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Prototype Early Warning Fire Detection System: Test Series 4 Results

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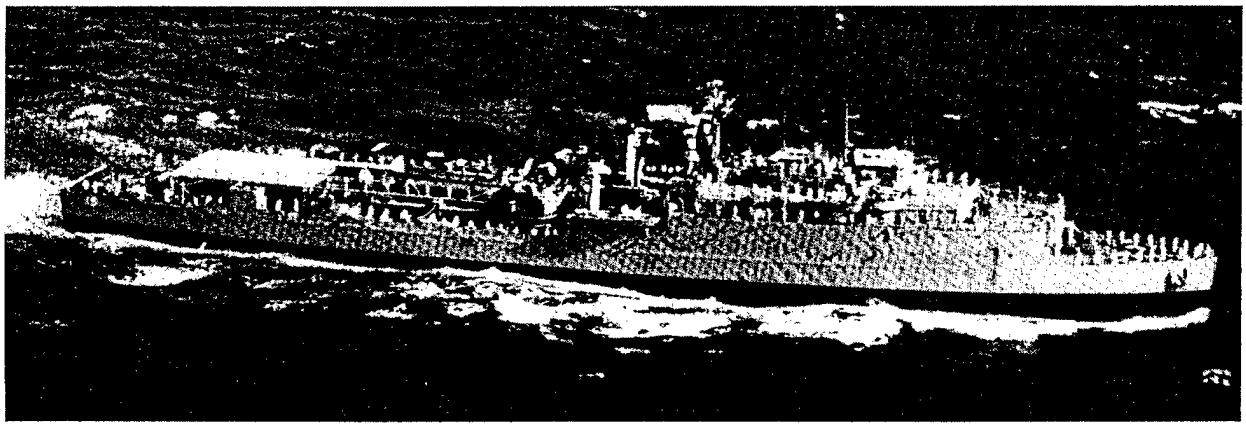

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14. ABSTRACT

This test series has demonstrated the successful operation of the early warning fire detector (EWFD) system over twelve compartments on two decks of the ex-USS *Shadwell* providing continuous monitoring of the spaces. The EWFD system responded to both flaming and smoldering fires while maintaining an immunity to nuisance sources. The use of multiple sensors and the Probabilistic Neural Networks alarm algorithm in the EWFD system resulted in improved performance compared to only an ionization or photoelectric smoke detector. The improved performance was illustrated in the comparative results of the EWFD system and the system sensor smoke detectors that were used as part of the EWFD system.

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PROTOTYPE EARLY WARNING FIRE DETECTION SYSTEM: TEST SERIES 4 RESULTS

1.0 INTRODUCTION

This work is a continuation of a multi-year effort to develop an early warning fire detection (EWFD) system that is highly immune to nuisance alarms. The work is being conducted under the Office of Naval Research (ONR) sponsored program Damage Control-Automation for Reduced Manning (DC-ARM) as part of a smart system capable of providing automated damage control. In previous years, efforts have focused on identifying appropriate sensors and candidate multivariate alarm algorithms [1,2,3,4]. Based on this work, different prototype detection systems were evaluated in real-time operation during three test series [5-9] and a demonstration [10] onboard the ex-USS *Shadwell*, the Naval Research Laboratory's full-scale fire research facility in Mobile, Alabama [11]. The FY01 work is aimed at refining and improving the alarm algorithm based on the data obtained during the FY00 test series and to develop a 14 unit prototype detection system that will operate in real-time. This test series (Series 4) is being conducted to evaluate the implementation of the expanded alarm system and to evaluate various aspects of performance. The test series was conducted from February 26 – March 9, 2001.

2.0 OBJECTIVE

The specific objectives of this test series were as follows:

1. Implement and verify the proper operation of the 14 unit EWFD system that will cover twelve spaces on the second and third decks in the forward section of the ship, and

2. Evaluate the performance of the fire detection system with the latest version of the alarm algorithm. A wide range of conditions was evaluated, including varying source sizes, locations of the sources with respect to detectors and varying compartment configurations and ventilation conditions.

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3.0 APPROACH

This test series consisted of exposing the multi-sensor prototype fire detectors to both real fire and nuisance sources while installed onboard the ex-USS *Shadwell*. The prototype detectors (i.e., the sensors that make up the detector) were monitored using a standard data acquisition system interfaced with a computer. The data was processed in real-time to provide an output indicating either normal or fire conditions. The sensor data and the output of the detection alarm algorithm were stored and sent to a display computer in the Control Room via the fiber optic Ethernet.

The prototype detection system was installed in the forward area of the ship on the second and third decks, in the compartments between Frames 11-29. The test area is depicted in Figures 1 and 2. The sources used consisted of new sources as well as some that were used in previous test series [5,6,9]. The standard test procedure was to continuously expose the prototype fire detectors to normal compartment conditions, followed by an exposure to a fire or nuisance source and then to ventilate the affected spaces. The detection system was continuously operating throughout the tests.

4.0 EXPERIMENTAL SETUP

4.1 Test Area and Closures

The test area for this series was FR 11 to 29 on the second deck and third deck, corresponding to the general test area for the DC-ARM demonstration [10]. Figure 1 and Figure 2 show the test area with the location of the EWFD prototypes. The ventilation in the test area consisted of using the Total Protection Exhaust System (TPES) and the Total Protection Supply System (TPSS) [12]. In general, most doors and hatches were open within the test area, but the test area was isolated from weather and the rest of the ship. The basic closure plan is presented in Table 1.

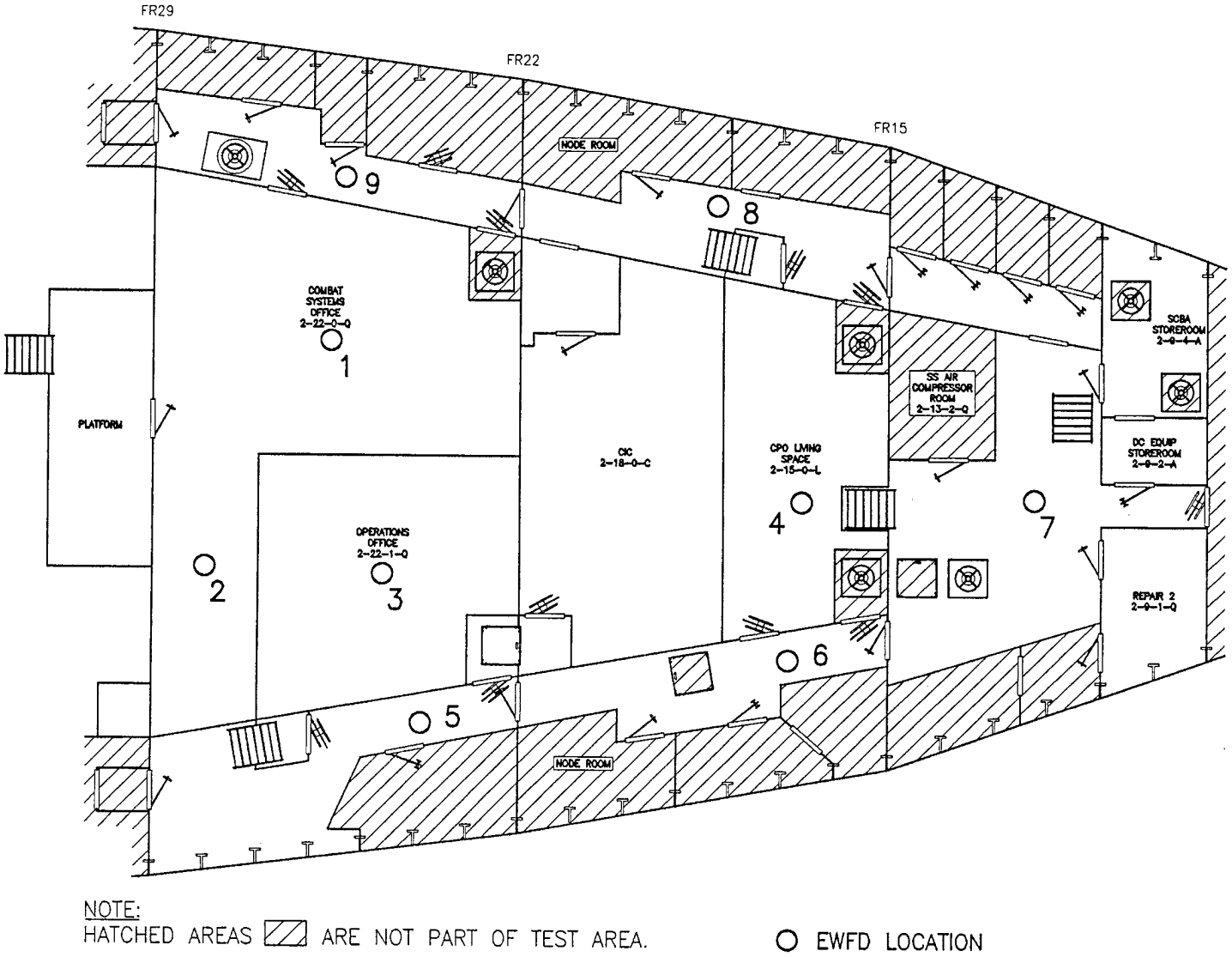

Figure 1 – Second Deck Detection Layout

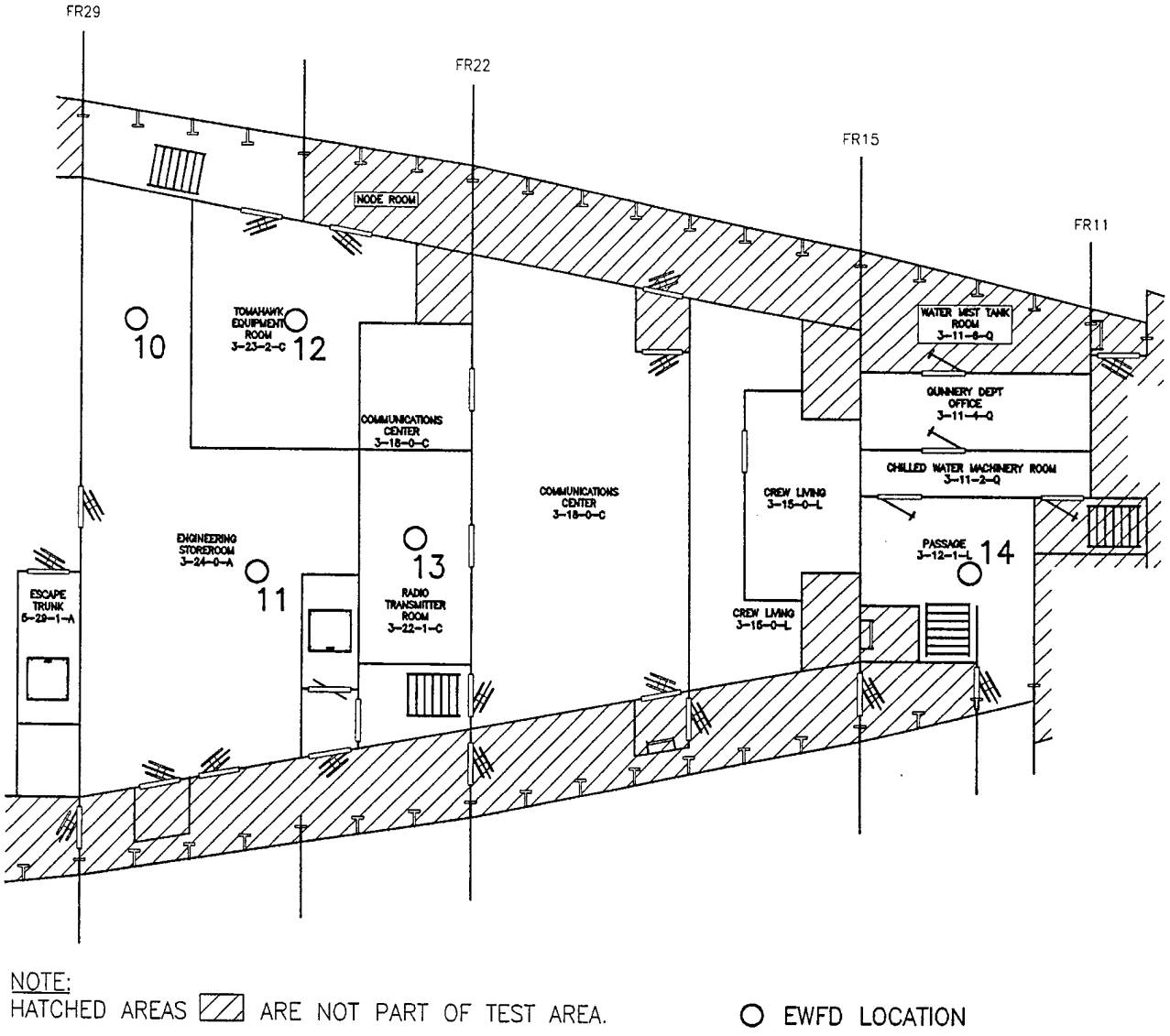

Figure 2 – Third Deck Detection Layout

Table 1. Summary of Basic Closure Plan

Number	Fitting Designation	Status
1	All doors to outboard spaces on Second Deck	Closed
2	WTD 2-19-2	Closed
3	QAWTD 2-26-2	Open
4	WTD 2-22-8	Open
5	WTH 2-18-2	Closed
6	QAWTD 2-17-2	Closed
7	WTD 2-15-4	Open
8	WTH 2-11-2	Closed
9	JD 2-10-0	Closed
10	QAWTD 2-9-1	Closed
11	WTD 2-11-1	Closed
12	QAWTH 2-13-1 (to third deck)	Open
13	WTH 2-14-1	Closed
14	WTD 2-15-3	Open
15	QAWTD 2-17-1	Open
16	WTH 2-18-1	Closed
17	WTD 2-22-5	Open
18	QAWTD 2-22-3	Open
19	QAWTD 2-26-1	Closed
20	WTD 2-29-1	Closed
21	WTD 2-29-0	Closed
22	QAWTD 2-26-0	Open
23	QAWTD 2-22-2	Open
24	QAWTD 2-22-1	Open
25	QAWTD 2-22-4	Open
26	WTD 2-20-2	Open
27	QAWTD 2-21-1	Open
28	JD 2-18-1	Open
29	QAWTD 3-25-2	Open
30	QAWTD 3-24-2	Closed
31	QAWTD 3-25-0	Open
32	QAWTD 3-24-1	Open
33	QAWTD 3-26-1	Closed
34	QAWTD 3-27-1	Closed
35	QAWTD 3-29-1	Closed
36	QAWTD 3-23-1	Open
37	QAWTD 3-22-3	Open
38	QAWTD 3-18-2	Closed
39	QAWTD 3-18-1	Closed
40	QAWTD 3-18-3	Open
41	QAWTD 3-15-1	Open
42	QAWTD 3-13-1	Open
43	WTD 3-14-0	Closed

4.2 Ventilation

The ventilation in the test area was via the Total Protection Supply System (TPSS) and the Total Protection Exhaust System (TPES). The total supply flow rate was 3079 cfm and the total exhaust flow rate was 3150 cfm. Appendix A presents the measured flow rate data for each space and fitting within the test area.

4.3 Prototype Fire Detection System

Fourteen EWFD prototypes were evaluated. In general, the detection system consisted of a group of sensors, a data acquisition system and a computer to implement the alarm algorithm Probabilistic Neural Networks (PNN) processing and data storage and display. The details of the prototype detectors are discussed in the following sections.

4.3.1 Sensors

All fourteen prototype detectors consisted of the same group of sensors and probabilistic neural network (PNN) alarm algorithm. Table 2 shows the sensor details for all of the prototypes. The sensors of a detector were mounted together as a single assembly.

Table 2. Details of Prototype Fire Detectors

No.	*Species*	*Sensor Range*	*Resolution*	*Instrument Model No.*	*Manufacturer*
1	Ionization smoke detector	ΔMIC ~ 40		1251 with base no. B501	System Sensor
2	Photoelectric smoke detector	0.052-12.5 %/m (0.016-4 %/ft)	0.052 %/m (0.016 %/ft)	2251 with base no. B501	System Sensor
3	Carbon monoxide ($CO_{100\ ppm}$)	0-100 ppm	0.5 ppm	TB7F-1A	City Technology
4	Carbon dioxide (CO_2)	0-5000 ppm	Accuracy = greater of ±5% of reading or ±100 ppm	2001V (EWFD1 and 2 only), 8002W Ventostat	Telaire/ Engelhard

4.3.2 Data Acquisition and Processing

Each sensor was hard-wired to the data acquisition system, which was located in the starboard side Node Room (see Figure 1). The data acquisition system consisted of National Instruments hardware (SCXI 1001 Chassis, SCXI 1100 modules and SCXI 1303 Terminal Blocks) controlled via LabVIEW 6.0 full development software. The data acquisition system was operated using a Dual Pentium 200MHz PC computer running Windows NT (128MB RAM). The LabVIEW software was used with a dynamic link library (DLL) file to execute the PNN alarm algorithm in real time. The data acquisition/processing system was synchronized in time with the Simplex smoke detection system permanently installed on the ship [13]. The EWFD system ran continuously and saved key information, such as text comments and warning and alarm times, to a history file. In addition, the sensor data from all fourteen prototypes was saved to a file at 2 second intervals for a set period of time 30 minutes before to 30 minutes after each event. The system was programmed to log data once probability value of 0.75 (the warning level) was reached. For nuisance source tests, a detector remote from the source (i.e., not involved in the test) was intentionally alarmed to start the recording of data before the test.

Each prototype detector provided four sensor responses to the PNN. Preprocessing of the sensor responses consisted of background subtraction. The ionization detector outputs were then converted from ΔMIC to percent obscuration/ft then to percent obscuration/m and the photoelectric detector outputs were converted from percent obscuration/ft to percent obscuration/m. The resulting pattern (sensor responses) was added to the end of a 25×4 matrix, data_history, and the first row was removed from the matrix to maintain the size of the matrix. In this manner, new patterns were added and data_history was updated to reflect the 25 most recent points collected for the four sensors (ion, photo, CO and CO_2). From data_history, the pattern magnitudes (10 points) and slopes (25 points) were then computed and then autoscaled (mean zero and unit variance) using the means and standard deviations derived from the training set. The resulting pattern (a magnitude and slope for each sensor) was then submitted to the PNN algorithm, which determined the classification and probability of a fire event. The alarm state was triggered if the probability was greater than 0.85 for three or more consecutive predictions. The training set consisted of the laboratory [1] and field data [2,9], 160 fire/nuisance sources. The events included in this training set are shown in Table 3. Preprocessing (i.e., before PNN

execution) also included the evaluation of a logic statement alarm, which had been added earlier in the program to provide improved responses for long duration smoldering events. However, only one scenario met the criteria for the logic statement alarm.

Table 3. Summary of Real Fire and Nuisance Sources in Training Set

No.	Fire Source Description
1	Propane Burner
2	Heptane pool fire
3	JP-5 pool fire
4	JP-8 pool fire
5	Alcohol pool fire
6	Smoldering mattress
7	Flaming mattress (foam only)
8	Flaming mattress (loose bedding)
9	Flaming mattress (tucked bedding)
10	Smoldering pillow
11	Smoldering electrical cable - LSDSGU-14: cross-linked polyolefin jacket, silicon rubber insulation
12	Smoldering electrical cable - LSTHOF-9: cross-linked polyolefin jacket, ethylene propylene rubber insulation
13	Smoldering electrical cable - LSTPNW-1 ½: cross-linked polyolefin jacket, cross-linked polyethylene insulation
14	Igniting electrical cable - LSDSGU-14: cross-linked polyolefin jacket, silicon rubber insulation
15	Igniting electrical cable - LSTHOF-9: cross-linked polyolefin jacket, ethylene propylene rubber insulation
16	Igniting electrical cable - LSDSGU-50: cross-linked polyolefin jacket, silicon glass insulation
17	Office Trash Can fire
18	Pipe insulation (NH Armaflex) exposed to a propane fire
19	Pipe insulation coated with oil (NH Armaflex) exposed to a propane fire
20	Pipe insulation (Calcium silicate) exposed to a propane fire
21	Pipe insulation coated with oil (Calcium silicate) exposed to a propane fire
22	Polyimide acoustic insulation exposed to a propane fire
23	Nomex honeycomb wall panel (TODCO) exposed to a propane fire
24	Nomex honeycomb wall panel (Hexcel) exposed to a propane fire
25	Nomex honeycomb wall panel (TODCO) exposed to a flaming bag of trash
26	Electrical cable (LSDSGU-14) and pipe insulation next to flaming laundry pile
27	Pipe insulation (Calcium silicate) exposed to fuel oil (F-76)
28	Burning toast
29	Burning Pop-Tarts

Table 3. Summary of Real Fire and Nuisance Sources in Training Set (continued)

No.	Nuisance Source Description
1	Normal toasting
2	Toasting Pop-Tarts
3	Welding
4	Cutting steel with acetylene torch
5	Grinding steel
6	Grinding cinder block
7	Cutting lauan board (wood)
8	Burning popcorn in microwave
9	Gasoline engine exhaust
10	Electric heater and halogen lamps
11	People talking and moving around in the test compartment
12	Cigarette smokers

4.3.3 Detector Locations

The locations of the detectors are shown in Figures 1 and 2. The prototype detectors were co-located (within 0.5 m) with the SHADWELL COTS system. The SHADWELL system consisted of Simplex photoelectric and ionization smoke detectors (see Section 4.4). Table 4 represents the detector locations and designations for both the EWFD prototypes and the Simplex smoke detectors.

Table 4. Detector Locations and Designations

Compartment	Detector Location	EWFD Location ID (detector #)	Simplex Ion ID	Simplex Photo ID
Combat System Office (Port) 2-22-0-Q	2-25-2	1 (1)	55	56
Combat System Office (Stbd) 2-22-0-Q	2-27-1	2 (3)	104	57
Operation Office 2-22-1-Q	2-24-1	3 (18)	103	53
CPO Living 2-15-0-L	2-17-1	4 (15)	101	4
2nd Deck STBD Passageway (Aft) 2-22-1	2-24-1	5 (6)	44	43

Table 4. Detector Locations and Designations (continued)

Compartment	Detector Location	EWFD Location ID (detector #)	Simplex Ion ID	Simplex Photo ID
2nd Deck STBD Passageway (Fwd) 2-15-1	2-19-1	6 (2)	40	39
Athwartship Passageway 2-10-0	2-13-1	7 (4)	6	46
2nd Deck Port Passageway (Fwd) 2-15-2	2-16-2	8 (17)	65	66
2nd Deck Port Passageway (Aft) 2-22-2	2-26-2	9 (5)	72	73
Engineering Storeroom (Port) 3-24-0-A	3-27-2	10 (14)	107	96
Engineering Storeroom (Stbd) 3-24-0-A	3-25-1	11 (16)	94	95
Tomahawk Equipment Room 3-23-2-C	3-25-2	12 (11)	3	1
Radio Transmitter Room 3-22-1-C	3-23-1	13 (13)	106	93
3rd Deck Forward Passage 3-12-1-L	3-12-1	14 (12)	105	82

4.4 Additional Instrumentation

The performance of the prototype fire detectors was compared to the performance of the commercial ionization and photoelectric smoke detectors currently installed onboard ship (COTS Simplex system) as well as the smoke detectors incorporated into the EWFD prototypes. The shipboard system consisted of Simplex ionization detectors (Model 4098-9717) and Simplex photoelectric detectors (Model 4098-9714) monitored with a single alarm panel (Simplex Model 4020). The Simplex fire alarm system provided time of alarm data for the exposed detectors. The alarm verification feature was not enabled for these detectors. The alarm sensitivity of these detectors was set to 8%/m (2.5%/ft) for photoelectric and 4.2%/m (1.3%/ft) for ionization, which are the same settings used in the past test series for this program.

At each detector location, one thermocouple was mounted to monitor overhead temperatures at the detectors. These thermocouple measurements, as well as the standard DC-ARM sensor instruments [10], were recorded by the Masscomp based data acquisition system onboard the SHADWELL. The DC-ARM sensor measurements remained the same as those

SHADWELL. The DC-ARM sensor measurements remained the same as those used in the FY00 Demo [14] so that the data can be used for evaluation or training of the supervisory systems.

Table 5 shows additional optical density meters (ODMs) that were installed in selected spaces within 0.5 m of the EWFD prototypes. The ODMs utilize an 880 nm infrared (IR) light emitting diode (IRLED) and receptor arrangement over a 1.0 m (3.1 ft) path length [15]. Video cameras were installed so that each space (when involved in a test) had one camera viewing the source. The cameras were installed with extra cable to allow for the changing of position with the varied source locations. The DC-ARM, Ethernet-based video system was utilized during selected tests to assess the effectiveness of identifying sources visually at early stages in development.

Table 5. Additional Optical Density Meters (ODM) Mounted Next to EWFD Prototypes

EWFD Location ID	Location
12	Tomahawk Equipment Room
11	Engineering Storeroom
14	3rd Deck Forward Passage
3	Operations Office
1	Combat Systems Office
4	CPO Living
7	2nd Deck Athwartship Passageway

5.0 TEST SCENARIOS

Test scenarios consisted of exposing the prototype detectors to both real fire and nuisance alarm sources. The fire and nuisance sources selected for this test series were designed to represent different scenarios as well as variations of scenarios performed in Test Series 1 to 3. The goal was to create a diversified set of scenarios and conditions that could possibly occur onboard ship. It was intended that replicates of scenarios not be exact duplicates. Providing variation in scenarios allowed the detection system to be evaluated against a broader database, which should translate into a more robust system. Table 6 and Table 7 show the fire and nuisance sources evaluated, respectively. These Tables provide the general details of the scenarios. Additional details of the specific scenarios conducted are included in the Results section in Table 8, which presents a summary of all the tests conducted.

Table 6. General Description of Fire Sources

Scenario	Description
Smoldering bedding	Smoldering Bedding Material, 0.6 x 0.6 m. Initiated with a Calrod heater between mattress and layered bedding materials. The 700 W Calrod (Ogden, Model MWEJ05J1870) was a 14.7 cm (5 in.) long, 1.3 cm (0.5 in.) diameter, resistive heater. A Navy mattress (MIL-M-18351F(SH)) consisting of a 11.4 cm (4.5 in.) thick Safeguard polychloroprene foam core covered with a fire retardant cotton ticking was outfitted with the following items: Two sheets – Federal Specification DDD-S-281, One blanket – Federal Specification MIL-B-844, and One bed spread – Federal Specification DDD-B-151. One mock-up pillow – A Navy feather pillow (Federal Specification V-P-356, Type 4) and a pillowcase (Federal Specification DDD-P-351).
Flaming bedding	The same bedding materials and setup used for the smoldering scenario was ignited using a butane lighter applied to newspaper that was placed between the mattress and the blanket.
Flaming trashcan near bookshelf	A 6 L (1.6 gal) metal round trashcan lined with a plastic bag was filled with crumpled and folded newspaper and white paper. The trash was ignited using a match. The trashcan was positioned up against a metal shelf with two shelves of binders, books, papers, and manuals (vertically stored tightly together).
Smoldering cables	Five pieces of 0.3 m (12 in) long LSTSGU-9 cable (3 conductor, 10 awg) were bundled around a Calrod to create a smoldering source. The Calrod was powered at 120 V ac. In some cases, the cables transitioned to flaming.
Smoldering and flaming bathroom trashcan	A 6 L (1.6 gal) metal round trashcan lined with a plastic bag was loosely filled (~1/2 full) with bathroom trash (paper towels, toilet tissue, plastic bottles (e.g., shampoo, deodorant), small cardboard tissue box). The trash was ignited with a discarded cigarette. The cigarette would induce smoldering that would eventually transition to a flaming fire (~7 to 9 minutes after source initiation). A lit Camel cigarette was placed into the trash so that it was between pieces of paper/toilet tissue.
Cardboard box exposed to IPA spill fire	Cardboard boxes with packing materials were exposed to a small diameter IPA spill fires. Fires consisted of pouring an approximately0.09 m^2 (1 ft^2) pool of IPA next to the boxes and igniting it with a match.
Smoldering laundry	A pile of miscellaneous pieces of laundry was exposed to a Calrod inserted within the pile. The Calrod was energized at 60 Vac. The pile was approximately 0.03 m^3 (1 ft^3) in size.
F76 spill fire on deck	0.1 to 0.5 L of F76 was spilled on the deck and ignited using approximately 30 to 60 ml of heptane.
Smoldering boxes via welding of the deck below	A corrugated cardboard box packed with smaller boxes was placed on the steel deck. The deck was heated from below by someone welding on the overhead. The box was exposed to the hot steel and allowed to smolder.
Flaming trash bag against pipe insulation and cables	A trash bag from the mess was placed against pipe insulation and cables. Four pieces of 0.6 m (24 in) long LSTSGU-9 cable (3 conductor, 10 awg) were vertically arranged side by side. The insulation was a 0.45 m long section of elastomeric foam (black, NH Armaflex) with glass lagging cloth (mil-C-20079). Samples were painted with chlorinated Alkyd White. The plastic trash bag contained typical waste items, such as paper towels, newspaper, cans, food containers, and lunch debris. The dimensions of the bag were 2 m (6.5 ft) in circumference and 0.9 m (3 ft) deep. The bag was approximately half full. The bag was placed on the deck and ignited with a butane lighter at a spot between the bag and the pipe and cables.
Smoldering computer monitor and flaming computer monitor	A typical computer monitor was setup so that a hot Calrod would cause the interior surface of the plastic cover to pyrolize. A 1.6 cm (5/8 in.) diameter hole was drilled into the side of the monitor at the lower back corner. A Calrod was inserted into the hole so that it was parallel and against the back bottom edge. Various power settings were used during the tests. This scenario initially produced a smoldering source. In some of the scenarios, the plastic case of the computer monitor ignited resulting in a flaming fire.

Table 7. General Description of Nuisance Sources

Scenario	Description
Grinding bulkhead	A section of steel bulkhead was ground using a standard handheld grinding wheel. In some tests, the steel was painted with up to 3 to 5 layers of paint. Other tests consisted of rusty/dirty steel surfaces. The grinder used was a Black and Decker 4.5in Angle Grinder, Model 2750G, with an 11 cm (4.5 in.) diameter, 0.6 cm (0.25 in.) thick Norton General-Purpose Mini Disc grinding pad.
Engine exhaust	An engine was placed outside the test area in the third deck aft of the engineering storeroom. The exhaust from the diesel powered engine (Yanmar, Engine # 69914, engine output is 2.8kW (3.8PS/3600), max output 3.1kW (4.2PS/3600), displacement 0.199L.) was allowed to flow into the test area through the QAWTD 3-29-1, which was open.
Welding steel	The arc welding consisted of running multiple welds across a steel plate using a 0.32 cm (0.125 in.) number 7018 rod and a constant current setting of 100 A.
Toasting	Toasting Pop Tarts™ or other toaster foods. Eight pieces toasted on high, immediately followed by eight more.
Cutting steel	An oxy-acetylene torch with a #1 Victor tip was used to cut steel. In some tests, the steel had been painted.
Normal toasting (Toasting Pop-Tarts)	Normal toasting consisted of simultaneously toasting eight slices of bread in two, four slice toasters and repeating the process after the toast automatically popped up. The toasters (Toastmaster Model D165, 120 V, 50-60 Hz, 1700 W) were set to "dark". Different items were used in the tests, including white bread and Pop-Tarts.
Microwaving popcorn	A typical bag of microwave popcorn (ACT II, Light Butter, 3.5 oz bag) was cooked on high in a microwave oven (Panasonic, Model #NN-S540WF) for 3 to 4 minutes. In Test 156A the microwave was left on for ~10 minutes; the popcorn burned and produced significant amounts of smoke that vented from the microwave at about 4 to 4.5 minutes after it was turned on.
Soldering pipe	Stainless steel pipe was soldered using a torch (Victor O2/ Acet), solder and flux (Staysylv 15, Cu/Ni 9010)
Cutting wood	A circular saw was used to cut multiple strips of plywood, creating a dusty environment.

6.0 PROCEDURE

At the beginning of each day, the daily checklist was completed (APPENDIX B). Prior to each test, the test area was cleared of all personnel not involved with testing. The closure plan was set. When the fuel package was prepared and the safety team [16] was in position, video taping was started and the Masscomp data acquisition system was started. During the test, test personnel made visual observations and took photographs of the source. The test was terminated when both the prototype and commercial smoke detectors reached alarm levels or the test director determined that conditions had ceased to change. All communication during the tests was via the sound powered phones.

Since the EWFD system was setup to run continuously, multiple sources were used in remote spaces during the same test. As will be seen in the Results section of this report, each test (e.g., Test 148) actually represents multiple test scenarios (i.e., designated Test 148a, 148b, etc). For example, a smoldering mattress scenario was conducted on the third deck in the Tomahawk Equipment Room at the same time that a burning popcorn event was occurring on the second deck in the port passageway. The multiple sources were always conducted so that effluent from one scenario would not enter the space where another scenario was being conducted.

7.0 RESULTS

Table 8 presents a summary of all valid tests conducted (Tests 138 to 146 were invalid due to a data acquisition problem). As described in Section 6, multiple test scenarios appear for each test number (e.g., Test 147a and 147b). Table 8 provides the general classification information and event times for each test along with select comments.

Table 8. Summary of Tests Conducted

Test	*Fire type*	*Brief Description*	*Loc.*	*Date*	*Mass-Comp Start Time*	*Ignition / Initiation time*	*Transition to flaming fire time*	*Ventilation start time*	*Vent time (secs after initiation)*	*Test Comments*
147a	Nuisance	Grinding painted bulkhead	Radio Transmitter Room	3/6/01	08:38:56	08:44:05	N/A	08:56:08	723	Grinding on FR22 bulkhead.
147b	fire, flaming	Flaming trashcan near bookshelf	Combat Systems Office	3/6/01	08:38:56	08:44:26	N/A	08:56:08	702	Lit near top of trashcan with butane lighter. Location of trashcan and bookshelf was at FR24 next to Operations Office bulkhead (8' from FR22).
148a	nuisance	Engine exhaust from Well Deck	Well Deck (engine), Engineering Storeroom (sensors)	3/6/01	09:41:34	09:47:14	N/A	10:12:40	1526	Engine was placed 3 ft forward of FR 36. QAWTD 3-29-1 to Engineering Storeroom was opened for this test.
148b	fire, smoldering	Smoldering Cables	2nd Deck Port Passage	3/6/01	09:41:34	09:53:42	N/A	10:12:40	1138	Cables located on top of the door at 2-22-2 (6.5' above the deck). Calrod at 120 Vac Port doors of Tomahawk Equipment Room and Combat Systems Office were closed. Doors 2-22-2 and 2-21-2 also closed (i.e., doors from CIC office to 2nd deck port passage, and from CIC office to Combat Systems Office).
149a	fire, smoldering	Smoldering bedding	Tomahawk Equipment Room	3/6/01	11:21:25	11:29:06	N/A	12:09:20	2414	Bedding consisted of 2 sheets, wool blanket, pillow, cover, mattress, and ticking. Two cal-rods used, each set to 40V. Location was fwd port corner @ 3-24-2. Source location was 2' forward of FR25 and 6" from the port bulkhead. Door 3-25-2 open.
149b	nuisance	Welding Steel	Combat Systems Office	3/6/01	11:21:25	11:32:00	N/A	12:09:20	2240	Location was aft port corner, 2-28-2 (2'6" from FR29 bulkhead and 4' from the port bulkhead). 7 welding rods consumed during welding in CSO.
149c	nuisance	Welding Steel	Operations Office	3/6/01	11:21:25	11:46:40	N/A	12:09:20	2240	Started welding in Ops Office against the aft bulkhead (3ft starboard of port bulkhead). 6 welding rods consumed during welding in Ops Office.
150a	nuisance	Normal Toasting	Radio Transmitter Room	3/6/01	13:23:14	13:28:22	N/A	13:56:00	1658	8 slices of bread were toasted continuously. Two, 4-slice toasters were on top of a 55-gallon drum located 1'6" from the FR22 bulkhead and 1'6" from the port bulkhead. 48 total slices of bread were toasted. The toasters were moved closer to the sensors at 13:37:26 (after 16 slices) and moved back to original location at 13:43:45 (after 16 slices) Toasters were Black and Decker Versa-Toast, T1400-Type1.
150b	fire, smoldering/ flaming	Smoldering/ Flaming Cables	Operations Office	3/6/01	13:23:14	13:35:20	13:48:00	13:56:00	1240	Cables were in a bundle with calrod inserted into the center. Calrod was powered at 120V. Cable bundle was on the starboard bulkhead, 52" above the deck.

Table 8. Summary of Tests Conducted (continued)

Test	*Fire type*	*Brief Description*	*Loc.*	*Date*	*Mass-Comp Start Time*	*Ignition / Initiation time*	*Transition to flaming fire time*	*Ventilation start time*	*Vent time (secs after initiation)*	*Test Comments*
152a	nuisance	Toasting Pop-Tarts	Operations Office	3/6/01	15:11:36	15:17:08	N/A	15:40:01	1375	Eight Pop-Tarts were toasted at a time in two, 4-slice toasters. 24 Pop-tarts were toasted.
152b	fire, flaming	Flaming Bathroom Trashcan	Tomahawk Equipment Room	3/6/01	15:11:36	15:18:05	15:26:56	15:40:01	1316	A lit cigarette was put into a bathroom trashcan, which initially caused smoldering of toilet tissue and paper towels.
153a	fire, smoldering	Smoldering Laundry	CPO Living Space	3/6/01	16:01:53	16:07:06	N/A	16:25:18	1092	Laundry pile consisted of a denim skirt, sweat shirt (polyester), and a knitted sweater. The variac for the calrod was set to 40% of 140V. The laundry pile was located in the starboard corner.
153b	fire, flaming	F-76 Spill on Deck	Engineering Storeroom	3/6/01	16:01:53	16:07:36	N/A	16:25:18	1062	The F-76 mix consisted of ½ liter F-76, plus ~60 ml of heptane accelerant. The resulting spill was approximately 0.09m^2 (1ft^2). The source was located at 3-27-0.
154a	nuisance	Welding Steel	Athwartship Passageway	3/7/01	08:30:11	08:35:06	N/A	08:46:32	686	Welding on a steel stand at FR12. Stand was approximately 1'2" high, and 7' from stbd bulkhead. 7 welding rods were consumed during the test.
154b	fire, flaming	Cardboard Box w/ Packing Material exposed to IPA spill fire	Operations Office	3/7/01	08:30:11	08:35:40	N/A	08:46:32	652	A cardboard box (2'x2'x3') was filled with packing material (polystyrene peanuts) and ignited via a small IPA spill fire. Location was 4'6" from the aft bulkhead, next to the starboard bulkhead. Box was moved closer to the flaming spill at 08:37:18.
155a	fire, flaming	Flaming Trash Bag against pipe insulation and cables	3rd Deck Fwd Passageway	3/7/01	09:31:33	09:36:55	N/A	10:37:49	3654	A trash bag from the mess was leaning against the starboard bulkhead, 0.9 m (3') from the fwd bulkhead (FR 12).
155b	fire, smoldering/flaming	Smoldering Computer Monitor	Combat Systems Office	3/7/01	09:31:33	09:36:42	N/A	10:37:49	3667	Monitor was on a 3' high stand, in the port aft corner (2' from FR29 and 3'10" from port bulkhead). The Calrod was powered at 60V. Power was increased to 70V at 10:05:28 and increased to 80V at 10:16:55. Power was finally increased to 100V at 10:29:10.
155c	fire, flaming	Cardboard Box w/ Packing Material exposed to IPA spill fire	Tomahawk Equipment Room	3/7/01	09:31:33	10:00:25	N/A	10:37:49	2244	Box dimensions were 1'8" x 1'8" x 4" high and it contained brown paper wrapping and styrofoam. The box was located 1'4" from the starboard bulkhead and 2'6" from the forward bulkhead (FR22).
155d	fire, flaming	Flaming Computer Monitor	Combat Systems Office	3/7/01	09:31:33	10:05:28	10:30:45	10:37:49	1941	This is an extension of test 155b, starting when the variac was increased to 70V. Variac increased to 80V at 10:16:55. Variac increased to 100V at 10:29:10.

Table 8. Summary of Tests Conducted (continued)

Test	*Fire type*	*Brief Description*	*Loc.*	*Date*	*Mass-Comp Start Time*	*Ignition / Initiation time*	*Transition to flaming fire time*	*Ventilation start time*	*Vent time (secs after initiation)*	*Test Comments*
156a	fire, smoldering	Smoldering Bedding	Tomahawk Equipment Room	3/7/01	11:13:17	11:18:25	12:00:29	12:02:31	2646	Source location was 2'4" forward of FR27 and 2'6" from port bulkhead. Mattress and bedding was placed on top of a 55-gallon drum, and a Calrod was placed between the bottom sheet and the piled bedding with pillow on top. Calrod was operated at 48 V.
156b	nuisance	Micro-waving Popcorn	2nd Deck Stbd Passage at 2-20-1	3/7/01	11:13:17	11:18:25	N/A	12:02:31	2646	Source location is 1'6" from port bulkhead at FR20. Microwave was sitting on a 55-gallon drum. At 11:22:30 some smoke from microwave. Large amount of smoke from microwave at approximately 11:22:50. Microwave was on for approximately 10 minutes.
156c	nuisance	Micro-waving Popcorn	2nd Deck Stbd Passage at 2-19-1	3/7/01	11:13:17	11:37:54	N/A	12:02:31	1477	Microwave was moved 3' forward from location of 156b. Back of microwave was even with FR19, and the microwave was facing aft. Microwave was on for approximately 4 minutes. It was stopped after bag of popcorn was fully popped. At 11:42:53 the bag was opened with a small amount of smoke/steam. There was slight burning of popcorn.
156d	nuisance	Micro-waving Popcorn	CPO Living Space	3/7/01	11:13:17	11:52:35	N/A	12:02:31	596	Microwave was placed directly under EWFD sensors in CPO Living. Microwave was on for approximately 4 minutes. At 11:56:43 (248 sec after initiation) the microwave was opened and the bag was then opened with some smoke/steam from the bag.
157a	fire, smoldering	Smoldering Computer Monitor	Operations Office	3/7/01	13:33:56	13:39:00	13:46:45	14:12:26	2006	Monitor was on a stand, 3' above the deck. Stand location was 3' from stbd bulkhead and 3' from the aft bulkhead. The Calrod was operated at 100V.
157b	fire, smoldering	Smoldering Bathroom Trashcan w/ Cigarette	3rd Deck Forward Passageway	3/7/01	13:33:56	13:39:05	14:06:08	14:12:26	2001	Trashcan was located at FR12 against the starboard bulkhead. 2 cigarettes were used in this test (one after the other). The plastic-lined trashcan contained brown paper, toilet tissue and a folded section of newspaper.
158a	fire, smoldering	Smoldering Laundry	Athwartship Passageway	3/7/01	14:49:29	15:06:05	15:25:00	15:26:26	1221	Laundry pile consisted of a pair of cuordoroy pants (100% cotton), a t-shirt, and a pair of children's pants (50% cotton, 50% polyester). The Calrod was operated 60V. Laundry pile was located at 2-9-0.
158b	nuisance	Steel Welding	2nd Deck Port Passageway	3/7/01	14:49:29	15:06:10	N/A	15:26:26	1216	Welding occurred at 2-24-2. The 2-15-2 door was closed for this test. 5 welding rods were used in this test.
159a	fire, flaming	Flaming Trash Bag against pipe insulation and cables	Engineering Storeroom	3/7/01	16:10:07	16:15:24	N/A	16:43:57	1713	There were 4, 24" cables (LSTSGU-9) vertically supported and exposed to a flaming trash bag fire. The source was located 3' forward of FR 29, 4' port of center.
159b	nuisance	Normal Toasting	CPO Living Space	3/7/01	16:10:07	16:15:30	N/A	16:43:57	1707	Toasted 8 slices of bread on high, continuously. The toasters were sitting on top of a 55-gallon drum. The location of the toasters was at the centerline of FR17. Toasters were moved closer to the sensors at 16:21:13. Approximately 40 slices of bread were toasted in this test.

Table 8. Summary of Tests Conducted (continued)

Test	*Fire type*	*Brief Description*	*Loc.*	*Date*	*Mass-Comp Start Time*	*Ignition / Initiation time*	*Transition to flaming fire time*	*Ventilation start time*	*Vent time (secs after initiation)*	*Test Comments*
159c	fire, flaming	F-76 Spill Fire	3rd Deck Forward Passageway	3/7/01	16:10:07	16:23:12	N/A	16:43:57	1245	0.25 liter F-76 spill was located at FR13 (approx 1.5' x 1.5').
160a	fire, smoldering	Smoldering Bedding	Radio Transmitter Room	3/8/01	08:44:09	08:49:23	N/A	10:05:20	4557	Standard bedding setup. Location of the source was in the aft, port corner, near the centerline of FR23. Two Calrods were placed under the pillow and set to 40V each. Only one of the calrods was found to be working during this test.
160b	fire, flaming	F-76 Spill Fire	Combat Systems Office	3/8/01	08:44:09	8:49:48	N/A	10:05:20	4532	0.25 liter F-76 spill was located at FR27, 7' from the port bulkhead.
160c	nuisance	Steel Grinding	3rd Deck Forward Passageway	3/8/01	08:44:09	9:22:00	N/A	10:05:20	2600	Grinding was done on the FR 12 bulkhead.
161a	fire, smoldering	Smoldering Computer Monitor	Engineering Storeroom	3/8/01	11:09:25	11:15:00	N/A	11:55:20	2420	Monitor was on a 55-gallon drum 3' off the deck. The drum was 4' from the stbd bulkhead and 4' from FR28 bulkhead. The Calrod was initially energized at 50V and was increased to 70V at 11:44:44.
161b	nuisance	Cutting Steel	CPO Living Space	3/8/01	11:09:25	11:16:00	N/A	11:55:20	2360	Acetylene torch used on the painted deck just starboard of JD 2-18-0 (adjacent to FR 18 bulkhead).
161c	nuisance	Cutting Steel	Operations Office	3/8/01	11:09:25	11:25:05	N/A	11:55:20	1815	Cutting location was near FR26, 6'10" from the stbd bulkhead.
162a	fire, smoldering	Smoldering Cables	Radio Transmitter Room	3/8/01	13:03:03	13:08:39	N/A	13:30:29	1310	Calrod was inserted into bundle of five cables. Cable bundle was set on top of a cabinet (6' high) between FR22 and FR23, 3' from stbd bulkhead.
162b	nuisance	Toasting Pop-Tarts	3rd Deck Forward Passageway	3/8/01	13:03:03	13:08:40	N/A	13:30:29	1309	Toasters were set on top of 55-gallon drum (3' high), at FR 13. Pop-Tarts were continuously toasted (8 at a time, using 4 Apple and 4 Oreo type Pop-Tarts). Approximately 24 Pop-Tarts were toasted.
163a	nuisance	Grinding Painted Steel	Radio Transmitter Room	3/8/01	13:53:41	13:58:54	N/A	14:16:10	1036	Grinding occurred on the bulkhead at FR 24.
163b	fire, flaming	Flaming Trashcan against Bookcase	Combat Systems Office	3/8/01	13:53:31	13:58:58	14:11:50	14:16:10	1032	Bookcase was against the bulkhead between the Operations Office and Combat Systems Office at FR 27. The trashcan was immediately adjacent to the bookcase. It was 1' above the deck and filled with office paper and newspaper. Ignited with a butane lighter. However, flame extinguished and fire smoldered before transitioning to flame at 14:11:50.
164a	fire, flaming	Flaming Bedding	Engineering Storeroom	3/8/01	14:50:17	14:57:20	N/A	15:20:10	1370	Typical bedding setup with newspaper added. Bedding was on 55-gallon drum, with newspaper in between the mattress and the blanket. The newspaper was ignited with a butane lighter. The drum was 3'9" from the stbd bulkhead, at FR28.

Table 8. Summary of Tests Conducted (continued)

Test	*Fire type*	*Brief Description*	*Loc.*	*Date*	*Mass-Comp Start Time*	*Ignition / Initiation time*	*Transition to flaming fire time*	*Ventilation start time*	*Vent time (secs after initiation)*	*Test Comments*
164b	fire, smoldering	Smoldering Boxes heated via welding of the deck from below	CPO Living Space (box)	3/8/01	14:50:17	14:59:08	N/A	15:20:10	1262	Welding on overhead of Crew Living below CPO Living Space. The cardboard box was located directly over the hot spot where welding was being performed. The box was 16" x 21" x 10" high and had several small empty cardboard boxes inside. The location of the box was 3' from the stbd bulkhead at FR16.
165a	nuisance	Engine Exhaust from Well Deck	Well Deck (engine) Engineering Storeroom (sensors)	3/8/01	16:02:11	16:07:50	N/A	16:36:18	1708	Engine was located at FR 33 (3-33-0). Engine was stopped at 16:10:50 and restarted at 16:14:00. Engine was moved to aft of door 3-29-0. 2nd deck was isolated from the 3rd deck by closing doors 3-23-1 and 3-26-2.
165b	fire, flaming	F-76 Spill Fire	Operations Office	3/8/01	16:02:11	16:08:16	N/A	16:36:18	1682	Spill consisted of 100ml of F-76, located at FR23 near the centerline of the bulkhead (1' away). 2nd deck was isolated from the 3rd deck by closing doors 3-23-1 and 3-26-2.
165c	nuisance	Micro-waving Popcorn	Athwartship Passageway	3/8/01	16:02:11	16:15:29	N/A	16:36:18	1249	Microwave was located at FR13, 5' from the stbd bulkhead. 2nd deck was isolated from the 3rd deck by closing doors 3-23-1 and 3-26-2.
166a	fire, smoldering	Smoldering Cables	Engineering Storeroom	3/9/01	08:42:19	08:50:17	08:56:02	09:05:52	935	Calrod was inserted into bundle of cables and placed on top of the door between Tomahawk Equip. Room and Engineering Storeroom. The Calrod was operated at 120V.
166b	fire, flaming	Flaming Trashcan against Bookcase	Combat Systems Office	3/9/01	08:42:19	08:50:41	N/A	09:05:52	911	Bookcase was against the FR27 bulkhead between Operations Office and Combat Systems Office (alcove). The trashcan was filled with office paper and news paper. It was elevated 1' off the deck.
167a	nuisance	Wood Cutting	Operations Office	3/9/01	09:54:23	09:59:58	N/A	10:11:10	672	Cutting occurred at FR25, center of the compartment.
167b	fire, flaming	F-76 Spill Fire	CPO Living Space	3/9/01	09:54:23	10:01:03	N/A	10:11:10	607	Location of spill was between FR16 and FR17, 3'8" from the port bulkhead.
168a	fire, smoldering	Smoldering Cables	2nd Deck Stbd Passageway	3/9/01	11:03:55	11:09:16	N/A	11:23:30	854	The bundle of cables was located on top of the 2-15-1 door frame. The Calrod was operated at 120V.
168b	nuisance	Soldering Pipe	2nd Deck Port Passageway	3/9/01	11:03:55	11:09:40	N/A	11:23:30	830	Location was between FR23 and FR24, near the deck.
168c	nuisance	Grinding Steel	Tomahawk Equipment Room	3/9/01	11:03:55	11:09:50	N/A	11:23:30	820	Grinding was started on bare steel bulkhead at FR27. At 11:19:26, moved grinding location to painted port bulkhead at FR24.

Table 9 presents the response times and the corresponding individual sensor responses of the EWFD prototypes for each test scenario. These times represent post-test processed values using the PNN algorithm described above. The gas sensor responses represent the magnitude above the ambient background level and the CO and CO_2 values are the absolute measurements. The Table indicates the phase of the event (i.e., Flaming fire=F, Smoldering fire=S, and Nuisance=N) and whether the prototype correctly classified the event. In the case where the EWFD prototype did not alarm, a response time is given which corresponds to the time of the highest probability; the probability value is given in parentheses. The alarm responses of the Simplex smoke detectors are presented in Table 10. If a smoke detector did not alarm, the alarm response time is designated as DNA (Did Not Alarm).

The response times of the individual System Sensor photoelectric and ionization smoke detectors are presented in Table 11. Response times are reported for multiple alarm thresholds. For the ionization detectors, response times correspond to 0.82, 1.6 and 4.2 %Obsc./m (0.25, 0.5 and 1.3 %/ft). For the photoelectric detectors, response times correspond to 0.82, 1.6, 8 and 11 %Obsc./m (0.25, 0.5, 2.5 and 3.5 %/ft).

Table 12 presents a comparison of the ODM values measured at the location of the Simplex smoke detectors at the time of alarm for the detector. The Table shows that there is not good agreement between the measured ODM value and the nominal alarm sensitivity setting of the smoke detector.

Table 9. Summary of the EWFD Prototype Alarm Responses

Test 147a – Grinding Painted Bulkhead in Radio Transmitter Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
13	Radio Transmitter Room	547 (P= .6903)	28.96	0.16	-1	754.79	N	Y
Test 147b – Flaming Trashcan near Bookshelf in Combat Systems Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
1	Combat Systems Office (Port)	84	38.55	0.0832	5.73	601.45	F	Y
2	Combat Systems Office (Stbd)	178	20.08	0.95	17.13	1299.8	F	Y
Test 148a – Engine Exhaust from Well Deck								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
10	Engineering Storeroom (Port)	1194 (P= .7329)	4.16	0.07	9.6	392.41	N	Y
11	Engineering Storeroom (Stbd)	1074 (P= .6253)	21.41	0.07	4.63	549.69	N	Y
12	Tomahawk Equipment Room	797 (P= .1912)	1.38	0.06	-1.2	323.84	N	Y
13	Radio Transmitter Room	655 (P= .3530)	14.5	0.16	1.24	670.35	N	Y
Test 148b – Smoldering Cables in 2nd Deck Port Passage								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
8	2nd Deck Port Passageway (fwd)	676	9.34	2.4	13.05	290.76	S	Y
9	2nd Deck Port Passageway (aft)	820	8.83	2.49	9.58	303.19	S	Y
Test 149a – Smoldering Bedding in Tomahawk Equipment Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
12	Tomahawk Equipment Room	1912	5.81	2.72	12.23	355.9	S	Y
10	Engineering Storeroom (Port)	2216 (P= .3812)	0.76	0.62	3.49	413.97	S	N
11	Engineering Storeroom (Stbd)	2216	1.98	1.25	7.13	569.58	S	Y
13	Radio Transmitter Room	1430 (P= .4126)	2.41	0.4	-0.33	660.43	S	N

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 149b – Steel Welding in Combat Systems Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
1	Combat Systems Office (Port)	102 (P= .53271)	1.96	0.9835	1.19	618.63	N	Y
2	Combat Systems Office (Stbd)	442 (P= .3621)	10.03	0.43	1.98	368.57	N	Y
Test 149c – Welding Steel in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	1408 (P= .7764)	27.01	1.67	0.46	374.34	N	Y
Test 150a – Normal Toasting in Radio Transmitter Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
13	Radio Transmitter Room	227 (P= .4258)	29.01	0.15	-1.1	719.76	N	Y
Test 150b – Smoldering/Flaming Cables in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	1020	35.66	0.65	2.83	731.11	F	Y
Test 152a – Toasting of Pop-Tarts in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	193 (P= .2028)	10.52	0.03	-1.91	318.22	N	Y
Test 152b – Flaming Bathroom Trashcan in Tomahawk Equipment Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
12	Tomahawk Equipment Room	570	39.44	1.33	19.53	547.86	F	Y
10	Engineering Storeroom (Port)	962	3.54	0.42	26.76	723.46	F	Y
11	Engineering Storeroom (Stbd)	916	16.27	0.73	25.88	1104.2	F	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 153a – Smoldering Laundry in CPO Living Space								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
4	CPO Living Space	835	-2.41	1.09	29.35	430.12	S	Y
Test 153b – F-76 Spill on Deck in Engineering Storeroom								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
10	Engineering Storeroom (Port)	47	33.5	1.61	31.86	653.88	F	Y
11	Engineering Storeroom (Stbd)	37	34.15	3.19	12.93	672.68	F	Y
12	Tomahawk Equipment Room	153	29.07	2.17	9.63	486.83	F	Y
13	Radio Transmitter Room	115	41.44	4.86	18.08	975.85	F	Y
Test 154a – Steel Welding in Athwartship Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
7	Athwartship Passageway	229	43.84	1.63	3.66	464.32	N	N
Test 154b – Cardboard Box exposed to IPA Spill Fire in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	345	27.07	-0.06	14.64	875.18	F	Y
1	Combat Systems Office (Port)	507	23.98	4.7831	27.8	624.43	F	Y
2	Combat Systems Office (Stbd)	521	1.95	3.49	16.87	742.55	F	Y
Test 155a – Flaming Trash Bag against Pipe Insulation and Cables in 3rd Deck Forward Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
14	3rd Deck Forward Passageway	58	45.71	0.9	35.74	1024.6	F	Y
7	Athwartship Passageway	84	37.45	0.29	8.57	734.91	F	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 155b – Smoldering Computer Monitor in Combat Systems Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
1	Combat Systems Office (Port)	711	2.62	3.098	1.3	601.02	S	Y
2	Combat Systems Office (Stbd)	1407 (P= .1573)	0.66	0.13	1.93	483.46	S	N
Test 155c – Cardboard Box exposed to IPA Spill Fire in Tomahawk Equipment Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
12	Tomahawk Equipment Room	80	37.55	1.29	60.07	624.29	F	Y
10	Engineering Storeroom (Port)	152	-0.8	0.09	24.8	659.57	F	Y
11	Engineering Storeroom (Stbd)	128	11.35	0.08	11.49	721.61	F	Y
Test 155d – Flaming Computer Monitor in Combat Systems Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
1	Combat Systems Office (Port)	1597	13.76	2.6106	43.79	639.5	F	Y
2	Combat Systems Office (Stbd)	1705	5.53	3.64	6.1	506.06	F	Y
Test 156a – Smoldering Bedding in Tomahawk Equipment Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
12	Tomahawk Equipment Room	1690	2.38	2.95	13.73	355.68	S	Y
10	Engineering Storeroom (Port)	2002	-1.6	0.77	11.26	448.7	S	Y
11	Engineering Storeroom (Stbd)	1630	0.81	2.48	10.96	563.32	S	Y
13	Radio Transmitter Room	1746 (P= .3653)	0.39	0.77	2.31	702.39	S	N
Test 156b – Microwaving Popcorn in 2nd Deck Starboard Passage at 2-20-1								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
5	2nd Deck Stbd Passage (aft)	388 (P= .4748)	1.71	0.35	3.24	387.16	N	Y
6	2nd Deck Stbd Passage (fwd)	538 (P= .5084)	-3.02	0.73	-0.57	434.59	N	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 156c – Microwaving Popcorn in 2nd Deck Starboard Passage at 2-19-1								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
5	2nd Deck Stbd Passage (aft)	1551 (P= .3379)	1.18	0.28	2.12	382.35	N	Y
6	2nd Deck Stbd Passage (fwd)	373 (P= .5360)	-4.19	0.41	-0.74	456.73	N	Y
Test 156d – Microwaving Popcorn in CPO Living Space								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
4	CPO Living Space	280 (P= .5444)	-0.96	0.67	1.87	412.79	N	Y
Test 157a – Smoldering Computer Monitor in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	595	-0.87	0.44	40.3	347.93	F	Y
Test 157b – Smoldering Bathroom Trashcan in 3rd Deck Forward Passage								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
14	3rd Deck Forward Passageway	1660	37.57	1.13	16.65	1096.1	F	Y
7	Athwartship Passageway	1826	37.9	0.65	14.47	691.8	F	Y
Test 158a – Smoldering Laundry in Athwartship Passageway (2-9-0)								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
7	Athwartship Passageway	1134	-0.06	1.15	23.68	384.08	S	Y
Test 158b – Steel Welding in 2nd Deck Port Passageway (2-24-0)								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
9	2nd Deck Port Passageway (aft)	543	29.47	1.99	11.66	436.26	N	N
8	2nd Deck Port Passageway (fwd)	1311 (P= .2758)	1.66	0.09	1.58	247.98	N	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 159a – Flaming Trash Bag against Pipe Insulation and Cables in Engineering Storeroom								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
10	Engineering Storeroom (Port)	79	1.6	0.05	47.62	597.04	F	Y
11	Engineering Storeroom (Stbd)	115	38	0.31	29.76	714.84	F	Y
13	Radio Transmitter Room	869	14.55	1.26	15.13	1325.8	F	Y
Test 159b – Normal Toasting in CPO Living Space								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
4	CPO Living Space	505 (P= .2644)	16.44	0.01	-0.55	416.4	N	Y
Test 159c – F-76 Spill Fire in 3rd Deck Forward Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
14	3rd Deck Forward Passageway	21	35.3	4.97	21.08	872.29	F	Y
7	Athwartship Passageway	51	54.29	2.47	8.7	433.08	F	Y
Test 160a – Smoldering Bedding in Radio Transmitter Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
13	Radio Transmitter Room	2760	1.03	0.81	15.12	849.45	S	Y
Test 160b – F-76 Spill Fire in Combat Systems Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
1	Combat Systems Office (Port)	37	64.97	3.1566	7.95	712.41	F	Y
2	Combat Systems Office (Stbd)	57	43.55	2.5	7.27	828.83	F	Y
Test 160c – Steel Grinding in 3rd Deck Forward Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
14	3rd Deck Forward Passageway	117 (P= .8000)	22.86	0.42	-0.05	566.88	N	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 161a – Smoldering Computer Monitor in Engineering Storeroom								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
10	Engineering Storeroom (Port)	2037	1.51	2.61	-1.1	492.25	S	Y
11	Engineering Storeroom (Stbd)	2103	11.58	3.27	0.07	580.4	S	Y
Test 161b – Cutting Steel in CPO Living Space								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
4	CPO Living Space	153	32.89	-0.02	7.21	1078.1	N	N
Test 161c – Cutting Steel in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	250 (P= .8591)	24.77	0.1	0.45	442.78	N	Y
1	Combat Systems Office (Port)	254 (P= .4571)	10.9	0.1633	9.15	671.56	N	Y
2	Combat Systems Office (Stbd)	1206 (P= .1406)	1.9	0.06	2.32	484.78	N	Y
Test 162a – Smoldering Cables in Radio Transmitter Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
13	Radio Transmitter Room	494	0.85	1.21	8.83	839.96	S	Y
Test 162b – Toasting Pop-Tarts in 3rd Deck Forward Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
14	3rd Deck Forward Passageway	861 (P= .6130)	26.18	0.56	0.86	567.15	N	Y
Test 163a – Grinding Painted Steel in Radio Transmitter Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
13	Radio Transmitter Room	359 (P= .6081)	27.26	0.11	0.33	825.82	N	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 163b – Flaming Trashcan against Bookcase in Combat Systems Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
1	Combat Systems Office (Port)	653	1.05	0.4744	9.48	647.77	F	Y
2	Combat Systems Office (Stbd)	579	2.83	4.39	17.65	490.48	F	Y
Test 164a – Flaming Bedding in Engineering Storeroom								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
10	Engineering Storeroom (Port)	115	0.35	0.06	23.83	560.07	F	Y
11	Engineering Storeroom (Stbd)	81	1.4	0.05	18.05	723.52	F	Y
13	Radio Transmitter Room	335	11.2	0.6	6.69	926.38	F	Y
Test 164b - Smoldering Boxes heated via Welding of the Deck from below in CPO Living Space								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
4	CPO Living Space	937 (P=0.65)	-0.47	2.05	16.72	443.36	S	Y
Test 165a – Engine Exhaust From Well Deck entering Engineering Storeroom								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
10	Engineering Storeroom (Port)	1645 (P= .8230)	0.15	0.11	15.2	479.88	N	Y
11	Engineering Storeroom (Stbd)	1601 (P= .7639)	25.68	0.1	7.31	575.09	N	Y
13	Radio Transmitter Room	1639 (P= .5406)	23.03	0.07	4.29	776.68	N	Y
Test 165b – F-76 Spill Fire in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	47	34.59	1.84	8.4	446.95	F	Y
Test 165c – Microwaving Popcorn in Athwartship Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
7	Athwartship Passageway	216 (P= .2706)	1.61	0.2	0.78	400.38	N	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (continued)

Test 166a – Smoldering Cables in Engineering Storeroom								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
10	Engineering Storeroom (Port)	332	0.68	2.22	2.29	445.54	S	Y
11	Engineering Storeroom (Stbd)	744 (P= .8256)	40.97	1.13	3.52	766.2	F	N
13	Radio Transmitter Room	386 (P= .4945)	0.9	1.19	-0.32	729.17	F	N
12	Tomahawk Equipment Room	1964 (P= .4191)	0.06	0.1	0.3	304.6	F	N
Test 166b – Flaming Trashcan against Bookcase in Combat Systems Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
1	Combat Systems Office (Port)	94	33.86	0.4007	11.71	649.27	F	Y
2	Combat Systems Office (Stbd)	46	52.38	0.3	13.17	865.3	F	Y
Test 167a – Wood Cutting in Operations Office								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
3	Operations Office	869 (P= .1692)	-0.62	0.15	-1.89	277.15	N	Y
Test 167b – F-76 Spill Fire in CPO Living Space								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
4	CPO Living Space	54	42.51	0.97	7.1	972.09	F	Y
Test 168a – Smoldering Cables in 2nd Deck Starboard Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
5	2nd Deck Stbd Passage (aft)	61 (P= .2026)	0.66	0.1	1.42	396.01	S	N
6	2nd Deck Stbd Passage (fwd)	325	0.07	2.2	-0.43	494.2	S	Y

Table 9. Summary of the EWFD Prototype Alarm Responses (concluded)

Test 168b – Soldering in 2nd Deck Port Passageway								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
8	2nd Deck Port Passageway (fwd)	1051 (P= .2707)	3.36	0.14	-0.42	287.94	N	Y
9	2nd Deck Port Passageway (aft)	93	39.78	0.25	11.46	894.74	N	N
Test 168c – Steel Grinding in Tomahawk Equipment Room								
EWFD Unit	*Location*	*Alarm Time (sec after initiation)*	*Ion Level (ΔMIC)*	*Photo Level (%/ft)*	*CO (ppm)*	*CO_2 (ppm)*	*Test Phase @ Alarm*	*Correct Classification?*
12	Tomahawk Equipment Room	163 (P= .6240)	0.84	0.62	-1.36	395.08	N	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses

Test 147a – Grinding Painted Bulkhead in Radio Transmitter Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
106-Ion	Radio Transmitter Room	322	N	N
093-Photo	Radio Transmitter Room	DNA	N	Y
Test 147b – Flaming Trashcan near Bookshelf in Combat Systems Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
055-Ion	Combat Systems Office (port)	103	F	Y
056-Photo	Combat Systems Office (port)	165	F	Y
104-Ion	Combat Systems Office (stbd)	158	F	Y
057-Photo	Combat Systems Office (stbd)	315	F	Y
Test 148a – Engine Exhaust from Well Deck				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
107-Ion	Engineering Storeroom (port)	DNA	N	Y
096-Photo	Engineering Storeroom (port)	DNA	N	Y
094-Ion	Engineering Storeroom (stbd)	1055	N	N
095-Photo	Engineering Storeroom (stbd)	DNA	N	Y
003-Ion	Tomahawk Equipment Room	DNA	N	Y
001-Photo	Tomahawk Equipment Room	DNA	N	Y
106-Ion	Radio Transmitter Room	1066	N	N
093-Photo	Radio Transmitter Room	DNA	N	Y
Test 148b – Smoldering Cables in 2nd Deck Port Passage				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
065-Ion	2nd Deck Port Passage (fwd)	DNA	S	N
066-Photo	2nd Deck Port Passage (fwd)	643	S	Y
072-Ion	2nd Deck Port Passage (aft)	789	S	Y
073-Photo	2nd Deck Port Passage (aft)	835	S	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 149a – Smoldering Bedding in Tomahawk Equipment Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
003-Ion	Tomahawk Equipment Room	DNA	S	N
001-Photo	Tomahawk Equipment Room	1209	S	Y
107-Ion	Engineering Storeroom (port)	DNA	S	N
096-Photo	Engineering Storeroom (port)	DNA	S	N
094-Ion	Engineering Storeroom (stbd)	DNA	S	N
095-Photo	Engineering Storeroom (stbd)	1569	S	Y
106-Ion	Radio Transmitter Room	DNA	S	N
093-Photo	Radio Transmitter Room	DNA	S	N
Test 149b – Welding Steel in Combat Systems Office and Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
055-Ion	Combat Systems Office (port)	223	N	N
056-Photo	Combat Systems Office (port)	DNA	N	Y
104-Ion	Combat Systems Office (stbd)	DNA	N	Y
057-Photo	Combat Systems Office (stbd)	DNA	N	Y
103-Ion	Operations Office	1237	N	N
053-Photo	Operations Office	1357	N	N
Test 149c – Welding Steel in Combat Systems Office and Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	1237	N	N
053-Photo	Operations Office	1537	N	N
Test 150a – Normal Toasting in Radio Transmitter Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
106-Ion	Radio Transmitter Room	186	N	N
093-Photo	Radio Transmitter Room	DNA	N	Y
Test 150b – Smoldering/Flaming Cables in Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	915	F	Y
053-Photo	Operations Office	DNA	F	N

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 152a – Toasting of Pop-Tarts in Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	DNA	N	Y
053-Photo	Operations Office	DNA	N	Y
Test 152b – Flaming Bathroom Trashcan in Tomahawk Equipment Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
003-Ion	Tomahawk Equipment Room	559	F	Y
001-Photo	Tomahawk Equipment Room	555	F	Y
107-Ion	Engineering Storeroom (port)	DNA	F	N
096-Photo	Engineering Storeroom (port)	DNA	F	N
094-Ion	Engineering Storeroom (stbd)	732	F	Y
095-Photo	Engineering Storeroom (stbd)	1053	F	Y
Test 153a – Smoldering Laundry in CPO Living Space				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
101-Ion	CPO Living Space	DNA	S	N
004-Photo	CPO Living Space	820	S	Y
Test 153b – F-76 Spill on Deck in Engineering Storeroom				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
107-Ion	Engineering Storeroom (port)	36	F	Y
096-Photo	Engineering Storeroom (port)	33	F	Y
094-Ion	Engineering Storeroom (stbd)	25	F	Y
095-Photo	Engineering Storeroom (stbd)	25	F	Y
003-Ion	Tomahawk Equipment Room	165	F	Y
001-Photo	Tomahawk Equipment Room	144	F	Y
106-Ion	Radio Transmitter Room	92	F	Y
093-Photo	Radio Transmitter Room	92	F	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 154a – Steel Welding in Athwartship Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
006-Ion	Athwartship Passageway	59	N	N
046-Photo	Athwartship Passageway	81	N	N
Test 154b – Cardboard Box exposed to IPA Spill Fire in Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	319	F	Y
053-Photo	Operations Office	427	F	Y
055-Ion	Combat Systems Office (port)	502	F	Y
056-Photo	Combat Systems Office (port)	489	F	Y
Test 155a – Flaming Trash Bag against Pipe Insulation and Cables in 3rd Deck Forward Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
105-Ion	3rd Deck Forward Passage	54	F	Y
082-Photo	3rd Deck Forward Passage	46	F	Y
006-Ion	Athwartship Passage	64	F	Y
046-Photo	Athwartship Passage	166	F	Y
Test 155b – Smoldering Computer Monitor in Combat Systems Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
055-Ion	Combat Systems Office (port)	DNA	S	N
056-Photo	Combat Systems Office (port)	DNA	S	N
104-Ion	Combat Systems Office (stbd)	DNA	S	N
057-Photo	Combat Systems Office (stbd)	DNA	S	N
Test 155c – Cardboard Box exposed to IPA Spill Fire in Tomahawk Equipment Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
003-Ion	Tomahawk Equipment Room	59	F	Y
001-Photo	Tomahawk Equipment Room	76	F	Y
094-Ion	Engineering Storeroom (stbd)	138	F	Y
095-Photo	Engineering Storeroom (stbd)	442	F	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 155d – Flaming Computer Monitor in Combat Systems Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
055-Ion	Combat Systems Office (port)	1622	F	Y
056-Photo	Combat Systems Office (port)	1672	F	Y
104-Ion	Combat Systems Office (stbd)	DNA	F	N
057-Photo	Combat Systems Office (stbd)	1730	F	Y
Test 156a – Smoldering Bedding in Tomahawk Equipment Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
003-Ion	Tomahawk Equipment Room	2323	S	Y
001-Photo	Tomahawk Equipment Room	1489	S	Y
107-Ion	Engineering Storeroom (port)	DNA	F	N
096-Photo	Engineering Storeroom (port)	2680	F	Y
094-Ion	Engineering Storeroom (stbd)	DNA	F	N
095-Photo	Engineering Storeroom (stbd)	1491	S	Y
106-Ion	Radio Transmitter Room	DNA	F	N
093-Photo	Radio Transmitter Room	2154	S	Y
Test 156b – Microwaving Popcorn in 2nd Deck Starboard Passage at 2-20-1				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
044-Ion	2nd Deck Stbd Passage (aft)	DNA	N	Y
043-Photo	2nd Deck Stbd Passage (aft)	DNA	N	Y
040-Ion	2nd Deck Stbd Passage (fwd)	DNA	N	Y
039-Photo	2nd Deck Stbd Passage (fwd)	DNA	N	Y
Test 156c – Microwaving Popcorn in 2nd Deck Starboard Passage at 2-19-1				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
044-Ion	2nd Deck Stbd Passage (aft)	DNA	N	Y
043-Photo	2nd Deck Stbd Passage (aft)	DNA	N	Y
040-Ion	2nd Deck Stbd Passage (fwd)	DNA	N	Y
039-Photo	2nd Deck Stbd Passage (fwd)	DNA	N	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 156d – Microwaving Popcorn in CPO Living Space				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
101-Ion	CPO Living Space	DNA	N	Y
004-Photo	CPO Living Space	281	N	N
Test 157a – Smoldering Computer Monitor in Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	684	F	Y
053-Photo	Operations Office	600	F	Y
Test 157b – Smoldering Bathroom Trashcan in 3rd Deck Forward Passage				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
105-Ion	3rd Deck Forward Passage	1659	F	Y
082-Photo	3rd Deck Forward Passage	1867	F	Y
006-Ion	Athwartship Passage	1716	F	Y
046-Photo	Athwartship Passage	DNA	F	N
Test 158a – Smoldering Laundry in Athwartship Passageway (2-9-0)				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
006-Ion	Athwartship Passage	1180	S	Y
046-Photo	Athwartship Passage	906	S	Y
Test 158b – Steel Welding in 2nd Deck Port Passageway (2-24-0)				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
072-Ion	2nd Deck Port Passage (aft)	217	N	N
073-Photo	2nd Deck Port Passage (aft)	567	N	N
065-Ion	2nd Deck Port Passage (fwd)	DNA	N	Y
066-Photo	2nd Deck Port Passage (fwd)	DNA	N	Y
Test 159a – Flaming Trash Bag against Pipe Insulation and Cables in Engineering Storeroom				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
107-Ion	Engineering Storeroom (port)	81	F	Y
096-Photo	Engineering Storeroom (port)	123	F	Y
094-Ion	Engineering Storeroom (stbd)	112	F	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 159a – Flaming Trash Bag against Pipe Insulation and Cables in Engineering Storeroom (cont.)				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
095-Photo	Engineering Storeroom (stbd)	139	F	Y
106-Ion	Radio Transmitter Room	240	F	Y
093-Photo	Radio Transmitter Room	206	F	Y
Test 159b – Normal Toasting in CPO Living Space				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
101-Ion	CPO Living Space	1609	N	N
004-Photo	CPO Living Space	DNA	N	Y
Test 159c – F-76 Spill Fire in 3rd Deck Forward Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
105-Ion	3rd Deck Forward Passage	30	F	Y
082-Photo	3rd Deck Forward Passage	25	F	Y
006-Ion	Athwartship Passage	49	F	Y
046-Photo	Athwartship Passage	45	F	Y
Test 160a – Smoldering Bedding in Radio Transmitter Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
106-Ion	Radio Transmitter Room	DNA	S	N
093-Photo	Radio Transmitter Room	4419	S	Y
Test 160b – F-76 Spill Fire in Combat Systems Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
055-Ion	Combat Systems Office (port)	20	F	Y
056-Photo	Combat Systems Office (port)	24	F	Y
104-Ion	Combat Systems Office (stbd)	44	F	Y
057-Photo	Combat Systems Office (stbd)	95	F	Y
072-Ion	2nd Deck Port Passage (aft)	245	F	Y
073-Photo	2nd Deck Port Passage (aft)	DNA	F	N

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 160c – Steel Grinding in 3rd Deck Forward Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
105-Ion	3rd Deck Forward Passage	106	N	N
082-Photo	3rd Deck Forward Passage	DNA	N	Y
Test 161a – Smoldering Computer Monitor in Engineering Storeroom				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
107-Ion	Engineering Storeroom (port)	DNA	S	N
096-Photo	Engineering Storeroom (port)	2095	S	Y
094-Ion	Engineering Storeroom (stbd)	DNA	S	N
095-Photo	Engineering Storeroom (stbd)	1937	S	Y
Test 161b – Cutting Steel in CPO Living Space				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
101-Ion	CPO Living Space	68	N	N
004-Photo	CPO Living Space	DNA	N	Y
Test 161c – Cutting Steel in Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	79	N	N
053-Photo	Operations Office	DNA	N	Y
055-Ion	Combat Systems Office (port)	270	N	N
056-Photo	Combat Systems Office (port)	DNA	N	Y
104-Ion	Combat Systems Office (stbd)	DNA	N	Y
057-Photo	Combat Systems Office (stbd)	DNA	N	Y
Test 162a – Smoldering Cables in Radio Transmitter Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
106-Ion	Radio Transmitter Room	577	S	Y
093-Photo	Radio Transmitter Room	408	S	Y
Test 162b – Toasting Pop-Tarts in 3rd Deck Forward Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
105-Ion	3rd Deck Forward Passage	1216	N	N
082-Photo	3rd Deck Forward Passage	DNA	N	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 163a – Grinding Painted Steel in Radio Transmitter Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
106-Ion	Radio Transmitter Room	90	N	N
093-Photo	Radio Transmitter Room	DNA	N	Y
Test 163b – Flaming Trashcan against Bookcase in Combat Systems Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
055-Ion	Combat Systems Office (port)	813	F	Y
056-Photo	Combat Systems Office (port)	813	F	Y
104-Ion	Combat Systems Office (stbd)	793	F	Y
057-Photo	Combat Systems Office (stbd)	680	F	Y
Test 164a – Flaming Bedding in Engineering Storeroom				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
107-Ion	Engineering Storeroom (port)	168	F	Y
096-Photo	Engineering Storeroom (port)	159	F	Y
094-Ion	Engineering Storeroom (stbd)	63	F	Y
095-Photo	Engineering Storeroom (stbd)	105	F	Y
106-Ion	Radio Transmitter Room	260	F	Y
093-Photo	Radio Transmitter Room	318	F	Y
Test 164b - Smoldering Boxes heated via Welding of the Deck from below in CPO Living Space				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
101-Ion	CPO Living Space	DNA	S	N
004-Photo	CPO Living Space	780	S	Y
Test 165a – Engine Exhaust From Well Deck entering Engineering Storeroom				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
107-Ion	Engineering Storeroom (port)	1658	N	N
096-Photo	Engineering Storeroom (port)	DNA	N	Y
094-Ion	Engineering Storeroom (stbd)	1599	N	N

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (continued)

Test 165a – Engine Exhaust From Well Deck entering Engineering Storeroom (cont.)				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
095-Photo	Engineering Storeroom (stbd)	DNA	N	Y
106-Ion	Radio Transmitter Room	1608	N	N
093-Photo	Radio Transmitter Room	DNA	N	Y
Test 165b – F-76 Spill Fire in Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	39	F	Y
053-Photo	Operations Office	34	F	Y
Test 165c – Microwaving Popcorn in Athwartship Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
006-Ion	Athwartship Passage	DNA	N	Y
046-Photo	Athwartship Passage	DNA	N	Y
Test 166a – Smoldering Cables in Engineering Storeroom				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
107-Ion	Engineering Storeroom (port)	436	F	Y
096-Photo	Engineering Storeroom (port)	406	F	Y
094-Ion	Engineering Storeroom (stbd)	502	F	Y
095-Photo	Engineering Storeroom (stbd)	419	F	Y
106-Ion	Radio Transmitter Room	883	F	Y
093-Photo	Radio Transmitter Room	398	F	Y
003-Ion	Tomahawk Equipment Room	681	F	Y
001-Photo	Tomahawk Equipment Room	DNA	F	N
Test 166b – Flaming Trashcan against Bookcase in Combat Systems Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
055-Ion	Combat Systems Office (port)	86	F	Y
056-Photo	Combat Systems Office (port)	148	F	Y
104-Ion	Combat Systems Office (stbd)	37	F	Y
057-Photo	Combat Systems Office (stbd)	94	F	Y

Table 10. Summary of the Simplex Smoke Detector Alarm Responses (concluded)

Test 167a – Wood Cutting in Operations Office				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
103-Ion	Operations Office	DNA	N	Y
053-Photo	Operations Office	DNA	N	Y
Test 167b – F-76 Spill Fire in CPO Living Space				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
101-Ion	CPO Living Space	36	F	Y
004-Photo	CPO Living Space	67	F	Y
Test 168a – Smoldering Cables in 2nd Deck Starboard Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
044-Ion	2nd Deck Stbd Passage (aft)	DNA	S	N
043-Photo	2nd Deck Stbd Passage (aft)	DNA	S	N
040-Ion	2nd Deck Stbd Passage (fwd)	657	S	Y
039-Photo	2nd Deck Stbd Passage (fwd)	334	S	Y
Test 168b – Soldering in 2nd Deck Port Passageway				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
072-Ion	2nd Deck Port Passage (aft)	92	N	N
073-Photo	2nd Deck Port Passage (aft)	DNA	N	Y
065-Ion	2nd Deck Port Passage (fwd)	DNA	N	Y
066-Photo	2nd Deck Port Passage (fwd)	DNA	N	Y
Test 168c – Steel Grinding in Tomahawk Equipment Room				
SIMPLEX Unit	***Location***	***Alarm Time (sec after initiation)***	***Test Phase @ Alarm***	***Correct Classification?***
003-Ion	Tomahawk Equipment Room	1296	N	N
001-Photo	Tomahawk Equipment Room	DNA	N	Y

Table 11. Individual Response Times* (sec after source initiation) of the System Sensor Ionization and Photoelectric Smoke Detectors that were Part of the EWFD Prototypes

Test 147a – Grinding Painted Bulkhead in Radio Transmitter Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
13	Radio Transmitter Room	254	324	DNA	208	262	DNA	DNA
Test 147b – Flaming Trashcan near Bookshelf in Combat Systems Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
1	Combat Systems Office (Port)	69	71	98	128	136	552	626
2	Combat Systems Office (Stbd)	182	190	222	164	168	DNA	DNA
Test 148a – Engine Exhaust from Well Deck								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
10	Engineering Storeroom (Port)	DNA	DNA	DNA	DNA	DNA	DNA	DNA
11	Engineering Storeroom (Stbd)	1064	DNA	DNA	DNA	DNA	DNA	DNA
12	Tomahawk Equipment Room	DNA	DNA	DNA	DNA	DNA	DNA	DNA
13	Radio Transmitter Room	1010	1070	DNA	DNA	DNA	DNA	DNA
Test 148b – Smoldering Cables in 2nd Deck Port Passage								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
8	2nd Deck Port Passageway (fwd)	DNA	DNA	DNA	602	642	688	932
9	2nd Deck Port Passageway (aft)	994	1004	DNA	251	452	826	DNA
Test 149a – Smoldering Bedding in Tomahawk Equipment Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
12	Tomahawk Equipment Room	DNA	DNA	DNA	738	924	1686	2408
10	Engineering Storeroom (Port)	DNA	DNA	DNA	1064	1336	DNA	DNA
11	Engineering Storeroom (Stbd)	DNA	DNA	DNA	1796	2204	DNA	DNA
13	Radio Transmitter Room	DNA	DNA	DNA	1070	2092	DNA	DNA
Test 149b – Steel Welding in Combat Systems Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
1	Combat Systems Office (Port)	276	302	DNA	96	102	DNA	DNA
2	Combat Systems Office (Stbd)	756	DNA	DNA	426	596	DNA	DNA
Test 149c – Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	1372	1392	DNA	1030	1154	DNA	DNA
15	Operations Office	1028	1098	1356	896	948	DNA	DNA
Test 150a – Normal Toasting in Radio Transmitter Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
13	Radio Transmitter Room	189	213	DNA	DNA	DNA	DNA	DNA
Test 150b – Smoldering/Flaming Cables in Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	946	956	DNA	683	946	DNA	DNA
15	Operations Office	906	920	1062	603	835	DNA	DNA

Table 11. Individual Response Times* (sec after source initiation) of the System Sensor ionization and Photoelectric Smoke Detectors that were part of the EWFD Prototypes (continued)

Test 152a – Toasting of Pop-Tarts in Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	DNA	DNA	DNA	DNA	DNA	DNA	DNA
15	Operations Office	759	DNA	DNA	DNA	DNA	DNA	DNA
Test 152b – Flaming Bathroom Trashcan in Tomahawk Equipment Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
12	Tomahawk Equipment Room	562	564	652	556	556	DNA	DNA
10	Engineering Storeroom (Port)	DNA	DNA	DNA	860	1102	DNA	DNA
11	Engineering Storeroom (Stbd)	DNA	DNA	DNA	828	908	DNA	DNA
Test 153a – Smoldering Laundry in CPO Living Space								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
4	CPO Living Space	DNA	DNA	DNA	535	653	983	1027
Test 153b – F-76 Spill on Deck in Engineering Storeroom								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
10	Engineering Storeroom (Port)	43	47	59	31	31	77	77
11	Engineering Storeroom (Stbd)	35	37	49	23	23	31	51
12	Tomahawk Equipment Room	149	153	197	133	135	167	215
13	Radio Transmitter Room	111	113	121	91	91	113	113
Test 154a – Steel Welding in Athwartship Passageway								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
7	Athwartship Passageway	213	215	229	43	63	DNA	DNA
Test 154b – Cardboard Box exposed to IPA Spill Fire in Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	331	341	445	409	409	433	433
15	Operations Office	303	313	343	359	377	429	431
1	Combat Systems Office (Port)	511	513	521	497	497	499	501
2	Combat Systems Office (Stbd)	583	591	DNA	507	509	513	547
Test 155a – Flaming Trash Bag against Pipe Insulation and Cables in 3rd Deck Fwd P'way								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
14	3rd Deck Forward Passageway	50	52	60	44	46	126	158
7	Athwartship Passageway	72	78	96	112	130	DNA	DNA
Test 155b – Smoldering Computer Monitor in Combat Systems Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
1	Combat Systems Office (Port)	2897	3379	3401	439	445	701	3333
2	Combat Systems Office (Stbd)	1487	3517	DNA	3407	3413	3429	3451
Test 155c – Cardboard Box exposed to IPA Spill Fire in Tomahawk Equipment Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
12	Tomahawk Equipment Room	78	80	90	72	72	118	228
10	Engineering Storeroom (Port)	DNA	DNA	DNA	162	414	DNA	DNA
11	Engineering Storeroom (Stbd)	176	DNA	DNA	154	164	DNA	DNA

Table 11. Individual Response Times* (sec after source initiation) of the System Sensor ionization and Photoelectric Smoke Detectors that were part of the EWFD Prototypes (continued)

Test 155d – Flaming Computer Monitor in Combat Systems Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
1	Combat Systems Office (Port)	1171	1653	1675	269	451	1591	1607
2	Combat Systems Office (Stbd)	1761	1791	DNA	1681	1687	1703	1725
Test 156a – Smoldering Bedding in Tomahawk Equipment Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
12	Tomahawk Equipment Room	2606	2616	DNA	1426	1478	1644	1852
10	Engineering Storeroom (Port)	DNA	DNA	DNA	1878	1922	DNA	DNA
11	Engineering Storeroom (Stbd)	DNA	DNA	DNA	1550	1562	1618	2002
13	Radio Transmitter Room	DNA	DNA	DNA	1576	1606	DNA	DNA
Test 156b – Microwaving Popcorn in 2nd Deck Starboard Passage at 2-20-1								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
5	2nd Deck Stbd Passage (aft)	DNA	DNA	DNA	378	400	DNA	DNA
6	2nd Deck Stbd Passage (fwd)	DNA	DNA	DNA	522	526	DNA	DNA
Test 156c – Microwaving Popcorn in 2nd Deck Starboard Passage at 2-19-1								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
5	2nd Deck Stbd Passage (aft)	DNA	DNA	DNA	378	400	DNA	DNA
6	2nd Deck Stbd Passage (fwd)	DNA	DNA	DNA	522	526	DNA	DNA
Test 156d – Microwaving Popcorn in CPO Living Space								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
4	CPO Living Space	DNA	DNA	DNA	2328	2330	DNA	DNA
Test 157a – Smoldering Computer Monitor in Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	625	627	633	527	535	619	619
15	Operations Office	DNA	DNA	DNA	2065	2065	2093	2115
Test 157b – Smoldering Bathroom Trashcan in 3rd Deck Forward Passage								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
14	3rd Deck Forward Passageway	1649	1653	1669	1623	1639	1845	1925
7	Athwartship Passageway	1701	1751	1809	1665	1671	DNA	DNA
Test 158a – Smoldering Laundry in Athwartship Passageway (2-9-0)								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
7	Athwartship Passageway	1179	1181	1191	903	911	1173	1173
Test 158b – Steel Welding in 2nd Deck Port Passageway (2-24-0)								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
9	2nd Deck Port Passageway (aft)	107	123	733	55	61	DNA	DNA
8	2nd Deck Port Passageway (fwd)	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Test 159a – Flaming Trash Bag against Pipe Insulation and Cables in Engineering Storeroom								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
10	Engineering Storeroom (Port)	95	97	125	95	101	121	125
11	Engineering Storeroom (Stbd)	109	111	125	131	137	141	223
13	Radio Transmitter Room	191	199	DNA	161	179	419	DNA

Table 11. Individual Response Times* (sec after source initiation) of the System Sensor ionization and Photoelectric Smoke Detectors that were part of the EWFD Prototypes (continued)

Test 159b – Normal Toasting in CPO Living Space								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
4	CPO Living Space	521	DNA	DNA	DNA	DNA	DNA	DNA
Test 159c – F-76 Spill Fire in 3rd Deck Forward Passageway								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
14	3rd Deck Forward Passageway	17	19	31	11	11	17	19
7	Athwartship Passageway	41	43	49	35	37	63	91
Test 160a – Smoldering Bedding in Radio Transmitter Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
13	Radio Transmitter Room	DNA	DNA	DNA	2638	2748	DNA	DNA
Test 160b – F-76 Spill Fire in Combat Systems Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
1	Combat Systems Office (Port)	23	25	31	21	21	35	87
2	Combat Systems Office (Stbd)	55	55	61	35	41	63	87
Test 160c – Steel Grinding in 3rd Deck Forward Passageway								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
14	3rd Deck Forward Passageway	117	127	DNA	121	DNA	DNA	DNA
Test 161a – Smoldering Computer Monitor in Engineering Storeroom								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
10	Engineering Storeroom (Port)	DNA	DNA	DNA	1103	1479	2025	2103
11	Engineering Storeroom (Stbd)	DNA	DNA	DNA	847	1451	2095	2097
Test 161b – Cutting Steel in CPO Living Space								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
4	CPO Living Space	23	81	DNA	197	DNA	DNA	DNA
Test 161c – Cutting Steel in Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	70	96	106	56	58	DNA	DNA
15	Operations Office	86	88	94	58	DNA	DNA	DNA
1	Combat Systems Office (Port)	DNA	DNA	DNA	DNA	DNA	DNA	DNA
2	Combat Systems Office (Stbd)	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Test 162a – Smoldering Cables in Radio Transmitter Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
13	Radio Transmitter Room	DNA	DNA	DNA	340	344	556	558
Test 162b – Toasting Pop-Tarts in 3rd Deck Forward Passageway								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
14	3rd Deck Forward Passageway	831	859	DNA	859	887	DNA	DNA
Test 163a – Grinding Painted Steel in Radio Transmitter Room								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
13	Radio Transmitter Room	113	217	DNA	77	177	DNA	DNA

Table 11. Individual Response Times* (sec after source initiation) of the System Sensor ionization and Photoelectric Smoke Detectors that were Part of the EWFD Prototypes (continued)

Test 163b – Flaming Trashcan against Bookcase in Combat Systems Office								
EWFD Unit	Location	0.82 Ion	1.6 Ion	4.2 Ion	0.82 Photo	1.6 Photo	8.0 Photo	11.0 Photo
2	Combat Systems Office (Stbd)	785	787	791	379	505	571	573
1	Combat Systems Office (Port)	839	841	851	421	485	823	823
Test 164a – Flaming Bedding in Engineering Storeroom								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
10	Engineering Storeroom (Port)	265	323	415	197	199	353	419
11	Engineering Storeroom (Stbd)	353	535	DNA	121	139	321	323
13	Radio Transmitter Room	391	395	DNA	261	279	393	605
Test 164b - Smoldering Boxes heated via Welding of the Deck from below in CPO Living Space								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
4	CPO Living Space	DNA	DNA	DNA	379	507	DNA	DNA
Test 165a – Engine Exhaust From Well Deck entering Engineering Storeroom								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
10	Engineering Storeroom (Port)	DNA	DNA	DNA	DNA	DNA	DNA	DNA
11	Engineering Storeroom (Stbd)	1585	1605	DNA	DNA	DNA	DNA	DNA
13	Radio Transmitter Room	1623	DNA	DNA	DNA	DNA	DNA	DNA
Test 165b – F-76 Spill Fire in Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	45	47	57	27	29	DNA	DNA
15	Operations Office	33	35	41	23	23	47	DNA
Test 165c – Microwaving Popcorn in Athwartship Passageway								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
7	Athwartship Passageway	DNA	DNA	DNA	212	DNA	DNA	DNA
Test 166a – Smoldering Cables in Engineering Storeroom								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
10	Engineering Storeroom (Port)	774	996	DNA	296	304	376	382
11	Engineering Storeroom (Stbd)	506	524	DNA	486	512	DNA	DNA
13	Radio Transmitter Room	876	DNA	DNA	340	384	DNA	DNA
12	Tomahawk Equipment Room	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Test 166b – Flaming Trashcan against Bookcase in Combat Systems Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
1	Combat Systems Office (Port)	88	92	104	86	108	198	558
2	Combat Systems Office (Stbd)	38	40	46	46	64	112	322
Test 167a – Wood Cutting in Operations Office								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
3	Operations Office	DNA	DNA	DNA	DNA	DNA	DNA	DNA
15	Operations Office	DNA	DNA	DNA	DNA	DNA	DNA	DNA
Test 167b – F-76 Spill Fire in CPO Living Space								
EWFD Unit	***Location***	***0.82 Ion***	***1.6 Ion***	***4.2 Ion***	***0.82 Photo***	***1.6 Photo***	***8.0 Photo***	***11.0 Photo***
4	CPO Living Space	44	46	58	38	42	DNA	DNA

Table 11. Individual Response Times* (sec after source initiation) of the System Sensor ionization and Photoelectric Smoke Detectors that were Part of the EWFD Prototypes (concluded)

Test 168a – Smoldering Cables in 2nd Deck Starboard Passageway								
EWFD Unit	*Location*	*0.82 Ion*	*1.6 Ion*	*4.2 Ion*	*0.82 Photo*	*1.6 Photo*	*8.0 Photo*	*11.0 Photo*
5	2nd Deck Stbd Passage (aft)	DNA	DNA	DNA	DNA	DNA	DNA	DNA
6	2nd Deck Stbd Passage (fwd)	651	687	DNA	247	301	357	367
Test 168b – Soldering in 2nd Deck Port Passageway								
EWFD Unit	*Location*	*0.82 Ion*	*1.6 Ion*	*4.2 Ion*	*0.82 Photo*	*1.6 Photo*	*8.0 Photo*	*11.0 Photo*
8	2nd Deck Port Passageway (fwd)	DNA	DNA	DNA	DNA	DNA	DNA	DNA
9	2nd Deck Port Passageway (aft)	47	75	99	157	171	DNA	DNA
Test 168c – Steel Grinding in Tomahawk Equipment Room								
EWFD Unit	*Location*	*0.82 Ion*	*1.6 Ion*	*4.2 Ion*	*0.82 Photo*	*1.6 Photo*	*8.0 Photo*	*11.0 Photo*
12	Tomahawk Equipment Room	839	849	DNA	153	161	DNA	DNA

* DNA = Did Not Alarm

Table 12. Comparison of Optical Density Meter (ODM) Measurements and the Nominal Alarm Sensitivity Setting for the Simplex Smoke Detectors

Test #	Phase	Simplex ID	Detector Type	Alarm Time (sec)	Alarm Level (% Obsc/m)	ODM Value (% Obsc/m)	ODM Value Greater Than Alarm Level?
147B	Flaming	055	Ion	103	4.2	0.9	No
152B	Flaming	003	Ion	559	4.2	4.1	No
154B	Flaming	103	Ion	319	4.2	0.0	No
155A	Flaming	105	Ion	54	4.2	0.2	No
155C	Flaming	003	Ion	59	4.2	0.0	No
163B	Flaming	055	Ion	813	4.2	12.0	Yes
164A	Flaming	094	Ion	63	4.2	6.3	Yes
165B	Flaming	103	Ion	39	4.2	18.8	Yes
166B	Flaming	055	Ion	86	4.2	1.4	No
167B	Flaming	101	Ion	36	4.2	8.4	Yes
147B	Flaming	056	Photo	165	8.0	4.7	No
152B	Flaming	001	Photo	555	8.0	3.9	No
154B	Flaming	053	Photo	427	8.0	14.1	Yes
155A	Flaming	82	Photo	46	8.0	0.1	No
155C	Flaming	001	Photo	76	8.0	1.0	No
161A	Smoldering	095	Photo	1937	8.0	5.0	No
163B	Flaming	056	Photo	813	8.0	12.0	Yes
164A	Flaming	095	Photo	105	8.0	7.1	No
164B	Smoldering	004	Photo	780	8.0	5.2	No
165B	Flaming	053	Photo	34	8.0	17.7	Yes
166B	Flaming	056	Photo	148	8.0	4.6	No
167B	Flaming	004	Photo	67	8.0	15.6	Yes

8.0 ANALYSIS

The performance of the EWFD prototype system was compared to the performance of the commercial smoke detectors. The performance was evaluated based on the ability of the detection system to correctly classify events and on the response time of the system to alarm. The classification performance is presented in Figure 3. The bar graph in Figure 3 shows the percent of scenarios that were correctly classified for each means of detection (EWFD, Simplex smoke and System Sensor (SS) smoke). The number at the top of each bar represents the percent correctly classified for each type of event. The total number of scenarios was 19 flaming fires, 11 smoldering fires and 22 nuisance sources.

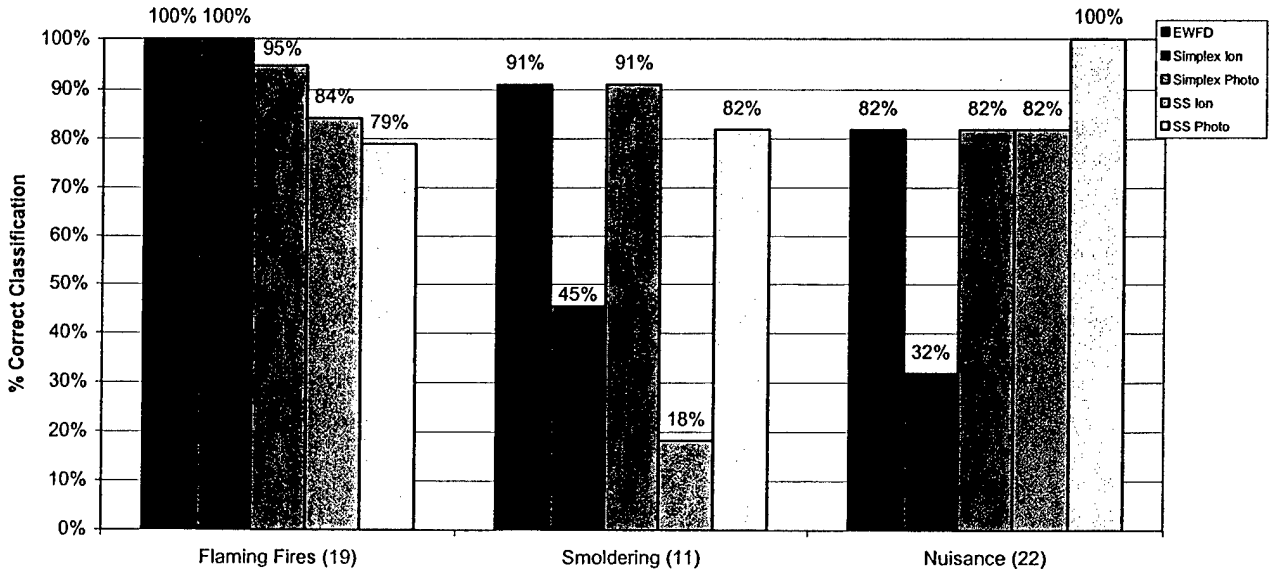

Figure 3 – Percent Correct Classification of Events by the EWFD Prototype Detection System Compared to the Commercial Smoke Detectors

Overall, the results show that the EWFD system had equivalent or better results than the commercial smoke detectors. The only exception was the System Sensor photoelectric detector which had a better classification rate for nuisance sources. Since the EWFD system included the System Sensor detectors, comparing the EWFD system to the System Sensor detectors provides the best assessment of the advantages of implementing a PNN alarm algorithm with multiple

sensors. As can be seen, the EWFD system provided better classification results for both flaming and smoldering sources compared to either the ion or photo detectors. The EWFD system had the same performance as the System Sensor ionization detector to nuisance sources, but showed a decrease compared to the photoelectric detector.

The EWFD showed a significant improvement over the performance of the Simplex ionization detector in both smoldering fire (100% vs. 45%) and nuisance source scenarios (82% vs. 32%) with equivalent performance to flaming fires (100% for both). The EWFD system correctly classified 82 percent of the nuisance sources (i.e., had a nuisance alarm rate of 18 percent). The Simplex ionization detector correctly classified 32 percent of the nuisance scenarios (a 64% nuisance alarm rate), where as all of the other smoke detectors had correct classification rates of 82 to 100 percent. Table 13 presents a list of the test scenarios that resulted in nuisance alarms for the EWFD prototype system. The scenarios were maintenance/repair operations, such as welding/soldering and cutting steel.

Table 13. Summary of Nuisance Source Scenarios that Resulted in Alarms for the EWFD Prototype System

Test	Nuisance Source	Location
154A	Welding steel	Athwartship Passageway
158B	Welding steel	2nd Deck Port Passageway
161B	Cutting steel	CPO Living
168B	Soldering pipe	2nd Deck Port Passageway

Table 14 compares the alarm times for each of the detectors. The alarm time reflects the first alarm for each type of detector in the room where the source was initiated. For most of the flaming fires, the response times of the EWFD system and the Simplex ionization detectors were the same (within 30 seconds of each other). This has been observed in earlier test series. However, for this test series, the Simplex photoelectric detector also responded to 9 out of 19 of the flaming fires within 30 seconds of the EWFD. This improved performance of the photoelectric detectors compared to previous test series is consistent with the use of larger fires in these tests. The EWFD system was almost 2 minutes slower than the Simplex ionization detector for test 150b (smoldering/flaming cables) and almost 2 minutes faster than the Simplex ionization detector in 157a (smoldering computer monitor) and 166a (smoldering cable). In each

of these tests, the EWFD system responded before the source transitioned to flaming. Generally, the System Sensor smoke detectors were slower to alarm than the Simplex smoke detectors and the EWFD system for flaming fires.

Table 14. Comparison of Alarm Times* (sec) for Detectors Within the Room of Origin

		EWFD		Simplex				System Sensor	
Test #	Phase	#	time	Ion #	Ion time	Photo #	Photo time	Ion	Photo
147B	F	01	84	055	103	056	165	98	552
150B	F	03	1020	103	915	053	DNA	DNA	DNA
152B	F	12	570	003	559	001	555	652	DNA
153B	F	11	37	094	25	095	25	49	31
154B	F	03	345	103	319	053	427	445	433
155A	F	14	58	105	54	082	46	60	126
155C	F	12	80	003	59	001	76	90	118
155D	F	01	1597	055	1622	056	1672	3401	1591
157A	F	03	595	103	684	053	600	633	619
157B	F	14	1660	105	1659	082	1867	1669	1845
159A	F	10	79	107	81	096	123	125	121
159C	F	14	21	105	30	082	25	31	17
160B	F	01	37	055	20	056	24	31	35
163B	F	02	579	104	793	057	680	851	823
164A	F	11	81	094	63	095	105	DNA	321
165B	F	03	47	103	39	053	34	57	DNA
166A	F	10	332	107	436	096	406	DNA	376
166B	F	02	46	104	37	057	94	46	112
167B	F	04	54	101	36	004	67	58	DNA
148B	S	08	676	072	789	066	643	DNA	826
149A	S	12	1912	003	DNA	001	1209	DNA	1686
153A	S	04	835	101	DNA	004	820	DNA	983
155B	S	01	711	055	DNA	056	DNA	3401	701
156A	S	12	1690	003	2323	001	1489	DNA	1644
158A	S	07	1134	006	1180	046	906	1191	1173
160A	S	13	2760	106	DNA	093	4419	DNA	DNA
161A	S	10	2037	107	DNA	096	2095	DNA	2025
162A	S	13	494	106	577	093	408	DNA	556
164B	S	04	DNA	101	DNA	004	780	DNA	DNA
168A	S	06	325	040	657	039	334	DNA	357
147A	N	13	DNA	106	322	093	DNA	DNA	DNA
148A	N	10	DNA	107	DNA	096	DNA	DNA	DNA
149B	N	01	DNA	055	223	056	DNA	DNA	DNA
149C	N	03	DNA	103	1237	053	1537	DNA	DNA
150A	N	13	DNA	106	186	093	DNA	DNA	DNA

Table 14. Comparison of Alarm Times* (sec) for Detectors Within the Room of Origin (concluded)

		EWFD		Simplex				System Sensor	
Test #	Phase	#	time	Ion #	Ion time	Photo #	Photo time	Ion	Photo
152A	N	03	DNA	103	DNA	053	DNA	DNA	DNA
154A	N	07	229	006	59	046	81	229	DNA
156B	N	05	DNA	044	DNA	043	DNA	DNA	DNA
156C	N	06	DNA	040	DNA	039	DNA	DNA	DNA
156D	N	04	DNA	101	DNA	004	281	DNA	DNA
158B	N	09	543	072	217	073	567	733	DNA
159B	N	04	DNA	101	1609	004	DNA	DNA	DNA
160C	N	14	DNA	105	106	082	DNA	DNA	DNA
161B	N	04	153	101	68	004	DNA	DNA	DNA
161C	N	03	DNA	103	79	053	DNA	106	DNA
162B	N	14	DNA	105	1216	082	DNA	DNA	DNA
163A	N	13	DNA	106	90	093	DNA	DNA	DNA
165A	N	10	DNA	107	1658	096	DNA	DNA	DNA
165C	N	07	DNA	006	DNA	046	DNA	DNA	DNA
167A	N	03	DNA	103	DNA	053	DNA	DNA	DNA
168B	N	09	93	072	92	073	DNA	99	DNA
168C	N	12	DNA	003	1296	001	DNA	DNA	DNA

* DNA = Did Not Alarm

The Simplex and System Sensor ionization detectors did not alarm for most of the smoldering fires. The System Sensor photoelectric detector was slower than either the Simplex photoelectric detector or the EWFD system for all but two smoldering fire tests, 155B and 161A. Figure 4 shows the average difference in response times between the EWFD system and the Simplex smoke detectors for all common tests. The average includes the differences for all tests in which both systems had a response. Overall for fire tests in which both systems alarmed, the average response times of the EWFD are about 0.5 to 3 minutes faster than the Simplex detectors. As seen in Figure 5, the EWFD system responded faster on average than the System Sensor smoke detectors. The nuisance source difference shown in Figure 5 is the result of only one test (158B). For the other common alarms, the EWFD system and the System Sensor ionization detectors alarmed at virtually the same time. For Test 158B, a welding scenario, the EWFD responded 190 seconds faster.

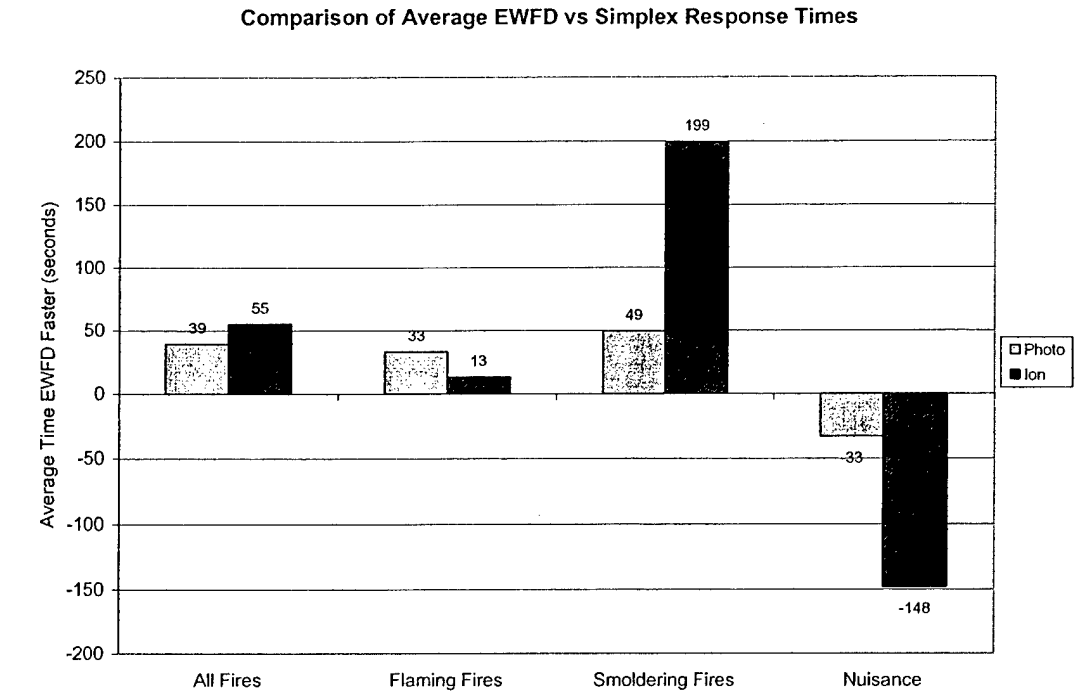

Figure 4 – Comparison of the Average Difference in Response Times for the EWFD vs. the Simplex Smoke Detectors for Scenarios in Which Both Alarmed

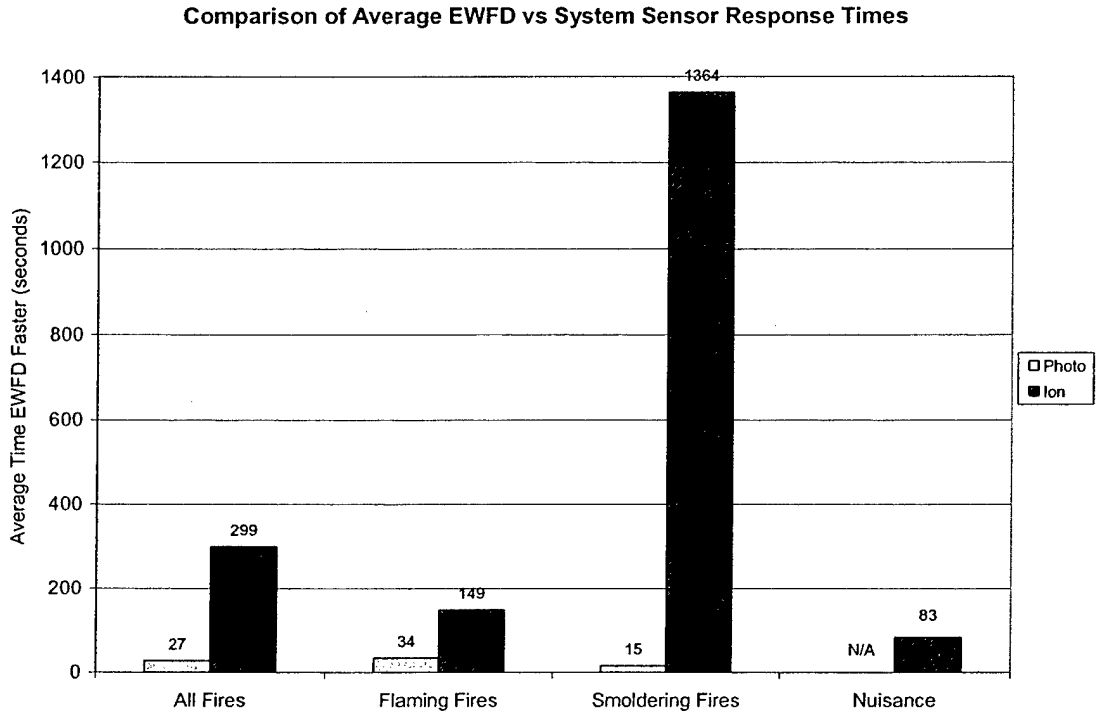

Figure 5 – Comparison of the Average Difference in Response Times for the EWFD vs. the System Sensor Smoke Detectors for Scenarios in Which Both Alarmed

The actual differences in alarm times were large in some tests. For example, the Simplex photoelectric detector responded 11 minutes faster than the EWFD system in one smoldering test (149a), however, the EWFD system alarmed 28 minutes faster than the Simplex photo in another smoldering test (160a). Some of the response time differences are due to the ventilation and flow dynamics in the compartments. In all the tests conducted in the Tomahawk Equipment Room, the EWFD was slower than the Simplex smoke detectors. Similar tests conducted in other compartments resulted in faster EWFD responses.

Training Set Compression

The training set used above contained 160 patterns, including 23 new events from Test Series 3 combined with the training set used in Test Series 3. The addition of the new patterns to the training set provides improved classification by filling in gaps in the data space. However adding more patterns to the training set also results in increased processing time for the algorithm to determine a probability. For real time application, longer processing time is a detriment to fast detection. One way to reduce the size of the training set is to find repetitive patterns in the training set. These patterns can then be removed from the training set without sacrificing classification performance.

The initial training set was reduced from 160 fire events to 76 by using a compression method that removed redundant information, while still providing important unique information. The compression method was implemented by first autoscaling the training set (mean zero and unit variance) and then calculating the distance between each point in the training set and every other point. This uses a similar technique as that used when making predictions of new events. The distances are stored in a distance matrix. From this distance matrix, the patterns were sorted into groups based only on its nearest neighbor. The groups were divided into, fires near fires (30), nonfires near nonfires (17), and fires (13) near nonfires (16). Each set of patterns in the 30 fire groups and 17 non-fire groups were averaged to generate a new pattern that would represent the original pattern. This reduced the 86 fire patterns to 30, and 45 non-fire patterns to 17. The mismatched patterns (13 fires/16 nonfires) were not averaged since they provide unique patterns in the data space along the boundary between fires and non-fires. This resulted in a reduction of

the training set from 160 patterns to 76 patterns (43/33) while still covering the same areas of the data space. The reduced training set maintained the same overall performance of the original training set.

9.0 CONCLUSIONS

The results of this test series have demonstrated the successful operation of the EWFD system distributed over twelve compartments on two decks providing continuous monitoring of the spaces. The EWFD system responded to both flaming and smoldering fires while maintaining an immunity to nuisance sources. The use of multiple sensors and the PNN alarm algorithm in EWFD system resulted in improved performance than was obtained using only a ionization or photoelectric smoke detector. This improved performance was illustrated in the comparative results of the EWFD system and the System Sensor smoke detectors that were used as part of the EWFD system.

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APPENDIX A

VENTILATION FLOW RATE DATA

This appendix presents the measured flow rate data taken during Test Series 4 of the TPSS and TPES fittings located on the second and third decks within the test area. Measurements were taken using a Dwyer vane anemometer.

Table A-1. Measured Ventilation Flow Rates at the TPSS and TPES Fittings

Space	Terminal	Measurement	Calibration Correction	Corrected Velocity (fpm)	Diameter (in)	Area (ft^2)	Flow rate (cfm)	Supply (cfm)	Exhaust (cfm)
3-25-1	4L Exhaust	Capped							
3-21-1	2N	453	-2.5	450.5	4.25	0.098	44	44	
3-21-3	2P	994	-25	969	8.5	0.394	382	382	
3-17-1	4M Exhaust	212	15.5	227.5	12.375 x 9.25	0.795	181		181
3-16-1	4N Exhaust	990	-24.5	965.5	6	0.196	189		189
3-13-1	2Q	1095	-32.5	1062.5	12	0.785	834	834	
3-11-1	4P Exhaust	634	-11.5	622.5	10	0.545	339		339
3-16-2	5N Exhaust	1595	-55	1540	11.5	0.721	1110		1110
3-21-2	3M	1361	-43	1318	11	0.660	869	869	
3-24-2	3L	Capped							
2-26-1	Exhaust	936	26.5	962.5	6	0.196	189		189
2-25-1	2E	Capped							
2-20-1	4G Exhaust	In Node room - closed to test area							
2-18-1	2L	919	-26	893	8.75	0.417	373	373	
2-16-1	2J	2050	-67.5	1982.5	4	0.087	173	173	
2-12-1	2K	205	15	220	8.75	0.417	92	92	
2-16-2	3F	1263	-38	1225	6.375	0.222	271	271	
2-18-2	Supply	209	15	224	5.75	0.180	40	40	
2-20-2	5K/5E exhaust from psgwy	2245	-79	2166	6	0.196	425		425
2-20-4	5G Exhaust	In Node room - closed to test area							0
2-25-2	5H Exhaust	754	-18	736	8.75 x 7.25	0.441	324		324
2-27-2	5J Exhaust	1088	32	1120	6	0.196	220		220
2-16-2	Exhaust	71	15	86	18 x 16	2.000	172		172
							Total =	**3079**	**3150**

APPENDIX B

TEST SHEETS

Early Warning Fire Detection Testing
Test Series 4
FY01
Daily Checklist

Date _____

VIDEO/AUDIO SYSTEM

_____ Video cameras on
_____ Video display monitors on
_____ Video cassette recorders on, tapes loaded, counters reset
_____ Date/Time generators on, adjust dates or times as necessary

INSTRUMENTATION

_____ Data acquisition systems on
_____ Gas analyzers are calibrated
_____ ODMs are calibrated
_____ Synchronize Masscomp clock with date/time generators
_____ Synchronize all computers with Masscomp
_____ Data collection program loaded and running

MECHANICAL SYSTEMS

_____ Main fire pumps on
_____ Backup fire pump checked

SAFETY SYSTEMS

_____ Protective clothing in well
_____ OBAs on hand
_____ Backup handlines flowed and positioned
_____ PKP/CO_2 extinguisher staged
_____ Ignition torches staged
_____ Two boats available and ready
_____ Coast Guard notified

TEST DAY CONCLUSION

_____ Backup data files and set data acquisition for overnight data collection (if applicable)
_____ Video cameras, monitors and recorders off
_____ Control room power supplies off
_____ Clean and recalibrate ODMs as needed
_____ Secure suppression system water supply

Early Warning Fire Detection Testing
Test Series 4
Test Sheet (page 1/2)

Test Name: EWFD _____ Date: _____

Description: (Space, EWFD units in space, source)_____

Ambient Conditions:
Temperature:_____(F) Rel. Humidity:_____(%)
Wind Speed:_____(mph) Wind Direction:_____(degrees)

_____ Test area and source photographed
_____ Make announcement:
_____ "Attention all personnel, fire testing is in progress. All personnel must clear Frames 11 to 29 on the main, second and third decks."
_____ Closure plan in effect.
_____ Sound Powered Phone check
___ Safety officer 1 .
___ Safety officer 2
_____ Test compartment evacuated (except for fueling personnel)
_____ Fire main charged
_____ Verify LabView operation
_____ Start Masscomp data acquisition
_____ Start videos
_____ Initiate source (Logic 1)
_____ Transition to flaming (if applicable) (Logic 2)
_____ Source terminated (Logic 3)
_____ Start ventilation (Logic 4)
_____ Stop video recorders
_____ Collect post source data

Post Test Turnaround
_____ Commence post fire shutdown as directed
_____ Safety team opens doors/hatches to vent test area as needed
_____ Monitor temperature and sensor data to determine return to baseline conditions

Comments: